TX
341
F69
v.1
no.3

FOOD TECHNOLOGY

CONTENTS

Editorials
- Instruction in Food Technology in the Universities and Colleges of the United States 299
- Food Is Fundamental 303
- Technological Tolerance 304
- A New Course in Food Technology 305

Carotene Retention in Carrots. Frank A. Lee and William T. Tapley 307

Fluorescence Spectra of Extracts of Dried Whole Egg Powder. James A. Pearce and W. A. Bryce 310

The Activity of Certain Cationic Germicides. G. J. Hucker, R. F. Brooks, Dorothea Metcalf, and Wm. van Esseltine 321

Objective Measurements of Quality in Foods. Howard R. Smith 345

A New Development in Solid Juice Concentrates. Laurence P. Geer 331

How California Instituted Sanitary Control in Food Plants. K. F. Meyer 334

Improving Sanitation Through Equipment Design. H. E. Kingman, Jr. 364

Chemical Agents Give Quality Improvements in Fisheries. Cecil G. Dunn 371

The Field Evaluation of Army Nutrition. Robert E. Johnson 384

The Transition of Army Food Research. Col. Rohland A. Isker 389

German Wartime Food Processing and Packaging. R. W. Pilcher 394

German Meat Packing and Fats and Oils Operations During the War Period. George T. Carlin 404

Salt and Its Place in the Food Industry. J. A. Dunn 415

Problems in the Production of Precooked Frozen Foods. Barbara L. Hutchings and Clifford F. Evers 421

Modernization of Food Processing Through Instrumentation. R. E. Clarridge 427

Simplified Modern Methods of Conveying, Brining, Washing, Syruping, and Precooling Commodities for Freezing and Preserving. Michel P. Vucasovich 442

Transportation of Fresh Fruits and Vegetables. D. F. Fisher 449

Food Technology in the Enforcement of the Food, Drug, and Cosmetic Act. Albert C. Hunter 451

Cost Determination and Allocation in Food Manufacturing Operations. W. L. Campbell 466

Proper Specification for Usage of Stainless Steel to Achieve Sanitation and Corrosion Resistance in Food Processing. Richard C. Cunningham 470

Detergents for Dairy Plants and Methods of Their Evaluation. H. G. Harding and H. A. Trebler 473

News of the Institute
- Achievement Award Presentation 19
- News of Regional Sections 23

Selected Abstracts 32

VOLUME 1, NO. 3, JULY, 1947

Published by the
INSTITUTE OF FOOD TECHNOLOGISTS

UNIVERSITY OF MICHIGAN LIBRARIES

FOOD TECHNOLOGY

Official Publication of
The Institute of Food Technologists

THE PROFESSIONAL SOCIETY OF FOOD TECHNOLOGISTS

C. OLIN BALL, *Editor*
G. J. HUCKER, *Managing Editor*

ASSOCIATE EDITORS

W. H. CATHCART
National Bakery Division
Great Atlantic & Pacific Tea Company
420 Lexington Avenue
New York 17, New York

H. C. DIEHL
Refrigeration Research Foundation, Inc.
410 Mercantile Building
Berkeley 4, California

HERMAN W. DORN
Lincoln Laboratories, Inc.
Decatur, Illinois

CHARLES N. FREY
Fleischmann Laboratories
Standard Brands, Inc.
New York, New York

J. L. HEID
Florida Citrus Canners Cooperative
Lake Wales, Florida

W. RAY JUNK
California & Hawaiian Sugar Refining Corp.
215 Market Street
San Francisco 5, California

M. L. LAING
Armour and Company
Chicago 9, Illinois

L. S. MCCLUNG
Department of Bacteriology
Indiana University
Bloomington, Indiana

EMIL M. MRAK
Food Technology Division
University of California
Berkeley, California

AKSEL G. OLSEN
Central Laboratories
General Foods Corporation
1125 Hudson Street
Hoboken, New Jersey

BERNARD L. OSER
Food Research Laboratories, Inc.
Long Island City, New York

BERNARD E. PROCTOR
Department of Food Technology
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

H. A. SCHUETTE
University of Wisconsin
Madison 6, Wisconsin

G. C. SCOTT
Minnesota Valley Canning Company
Le Sueur, Minnesota

PAUL F. SHARP
The Golden State Company
425 Battery Street
San Francisco, California

HARRY W. VON LOESECKE
U. S. Department of Agriculture
Washington, D. C.

PAUL C. WILBUR
Food Machinery Corporation
San Jose, California

Subscriptions. Price: $10.00 per volume in North and South America; $10.50 in all other countries. Prices are net, postpaid. New subscriptions and renewals are entered to begin with the first issue of the current volume. Renewals should be made promptly to avoid break in series. Subscriptions should be sent to The Institute of Food Technologists, Geneva, N. Y. Subscriptions at no cost for all members of the Institute of Food Technologists.

Published quarterly by The Institute of Food Technologists.

Copyright 1947 by the Institute of Food Technologists.

Printed in U. S. A. Domestic subscription and countries in North and South America, $10.00 per volume; $10.50 per volume in all other countries. Application pending for second-class permit at the Post Office, Champaign, Ill.

POLICIES AND PLANS

In the April issue of FOOD TECHNOLOGY, we published our first statement under this heading. In Boston, on June 3, the editorial board held a meeting, in which many matters were settled. It is appropriate, therefore, that in this, the third, issue of FOOD TECHNOLOGY, we state some newly established policies and plans.

The I. F. T. includes within its ranks scientists, engineers, executives, technicians, production workers, developers of machines, sales engineers, etc. Those in each sphere of activity have a predominating preference as to the type of material they want to see in this journal. Most of our readers have second, and perhaps, third choices which, to them, are almost as important as the first.

FOOD TECHNOLOGY cannot please all its readers to the fullest extent but will try very hard to please the majority. Its aim is to publish in each issue several papers giving new information gleaned from research work and several excellent reviews on technological subjects. In this way, we hope to give every reader some of the type of reading that he likes best, with the remainder being of types which he regards also as of real value to him. We have the policy of not publishing a second review paper on any one subject unless the second review contains significant information that the first published review did not contain.

The name of the section of abstracts undergoes a change with the present issue. The new title "Selected Abstracts" was chosen to indicate that the intention is not to cover the field of food technology . The abstracts are selected to be of the greatest possible value to readers whose access to the sources of abstracts that aim to cover completely the separate branches of food technology is limited.

A new system of pagination is instituted with the present number. Editorials and papers are carried in one system of page numbers while the other sections, viz, "News of the Institute" and "Selected Abstracts" are carried in a separate system of page numbers. This division is made for the convenience of those who desire, when binding the volumes, to separate sections.

Suggestions and criticisms by readers are solicited and will be welcomed.

Address of the editor: Owens-Illinois Glass Co., Toledo 1, Ohio.

Did You Miss One or Both of First Two Issues?

A number of members have informed Dr. Hucker that they received the April number of FOOD TECHNOLOGY, but not the January number. It is believed that some names were omitted by mistake from the list of those to whom the January number was sent. We impart the information now that a number of names was purposely omitted from the lists of those to whom both the January and the April issues were sent. These were the names of members who are not up-to-date in payment of dues. The present issue (July) is being mailed to all whose names appear on the membership list of the Institute. Anyone receiving this issue who did not receive either the January or the April issue, please inform the Managing Editor of this fact. If you are back in payment of dues, please remit to the Secretary-Treasurer, Dr. C. R. Fellers, University of Massachusetts, Amherst, Massachusetts and you will receive the first two issues of FOOD TECHNOLOGY.

INSTITUTE OF FOOD TECHNOLOGISTS

President: G. J. Hucker

Vice-President: E. M. Chace *Secretary-Treasurer:* C. R. Fellers

Councilors: Paul P. Aldrich, F. C. Blanck, L. V. Burton, W. L. Campbell, B. S. Clark, E. D. Clark, R. J. Cohee, F. W. Fabian, A. C. Fay, R. D. Gerwe, W. E. Graham, H. T. Griswold, E. H. Harvey, M. E. Highlands, Stroud Jordan, W. Ray Junk, John T. Knowles, Anthony J. Lorenz, Roy C. Newton, Aksel G. Olsen, B. L. Oser, Joseph R. Pardieck, W. D. Pheteplace, Jr., S. C. Prescott, A. C. Richardson, Paul F. Sharp, E. S. Stateler, H. W. Vahlteich, A. H. Warth, Jasper G. Woodroof, C. C. Zeigler.

The Institute of Food Technologists assumes no responsibility for statements in contributed articles appearing in FOOD TECHNOLOGY. Editorials present only opinions of the writers and do not necessarily reflect policies of the Institute of Food Technologists.

FOOD TECHNOLOGY

VOLUME 1 JULY, 1947 NUMBER 3

Editorial

Instruction in Food Technology in the Universities and Colleges of the United States—George F. Stewart[1]

In discussing this topic the author is very much conscious of the fact that we food technologists are still "babes in arms." The Institute was organized less than seven years ago. We are all still guilty of oversimplifying the problems we face to the point that we make a food technologist sound like one kind of "guy." It is well to remember that our present membership is made up of a very polyglot group. We scarcely understand each other's jargon. I should like to remind you that the Institute of Food Technologists consists of graduates of at least the following widely different curricula: bacteriology, chemical engineering, chemistry, dairy industry, agronomy, foods and nutrition, genetics, refrigeration engineering, animal husbandry, etc. We do have a few members who have received degrees in food technology itself and this fortuitous circumstance, I suppose, must make our society's name official.

It is significant, although humorous, to note that the first report of the Committee on Education and Curriculum issued in May 1944 contained this, among other propositions: ". . . there is a profession of food technology." Apparently there was doubt in the minds of some people as to the veracity of this proposition even at that late date and the Committee felt it to be desirable to go on record in an effort to clear up the matter.

Because of this state of affairs the author feels that there is need for a good deal of tolerance and understanding in connection with a survey of this sort, particularly in our making any attempt to evaluate the present college and university food technology curricula. I have chosen to study those college curricula that pertain more or less directly to food and not just those labeled food technology. I have kept in mind the definition of food technology as it is contained in the Constitution of the Institute in determining which curricula seemed capable of contributing directly to the training of food technologists.

At this point I should like to refresh your memory by reading Article II, "Definition of Food Technology."

"Food technology is the technological application of science and engineering to the manufacture and handling of foods. Food technology is primarily based on the fundamentals of chemistry, physics, biology and microbiology, any of which sciences may find expression through an engineering operation. Knowledge of food technology enables its possessor to develop new products, processes, and equipment, to select proper raw materials, to understand and control food manufacturing operations, to solve technical problems of food manufacture and distribution, including those involved in plant sanitation, and those affecting the nutritional value and public health safety of foods, and to know the fundamental changes of composition and of physical condition of foodstuffs which may occur during and subsequent to the industrial processing of the foodstuffs."

On careful perusal of the various curricula it has become increasingly apparent that there is much course work given in our colleges pertaining directly to food but which is not listed under food technology. More on this observation later.

[1] Chairman, Administrative Sub-Committee, Graduate Committee on Food Technology, Iowa State College.

Now, I should like to take up those curricula which appear to have been designed specifically for the training of food technologists. Besides those listed under food technology, curricula bearing such labels as food industries, food engineering and nutrition are included.

THE CURRICULA

At the present time there appear to be at least 16 colleges and universities offering degree work in food technology. They include:

Bucknell University	Oklahoma A & M College
Cornell University	Oregon State College
Illinois Institute of Technology	Pennsylvania State College
Iowa State College	Washington State College
Massachusetts Institute of Technology	University of California
Massachusetts State College	University of Maryland
Michigan State College	University of Minnesota
Ohio State University	University of Washington

In its first report the Committee on Education and Curricula listed several propositions relating to the requisites to a satisfactory curriculum in food technology. There was no formal action by the Committee on these propositions. Therefore, they should not be considered as recommendation of the Committee. Nonetheless they do provide the best basis available for comparing the different curricula which have been developed by our colleges and universities.

Comparisons on the basis of some of the more pertinent propositions are listed:

Proposition A. "That the students first acquire as a foundation certain basic courses applicable to all phases of food technology; such as courses in *chemistry, physics, mathematics, microbiology* and *biological chemistry.*"

Examination of the curricula shows that, in general, all of the schools have adhered to this idea although the specific nature and the extent of the basic scientific training varies widely among schools. For instance, one curriculum listed no required courses in mathematics while several others require mathematics through the calculus. Similar examples may be found in the requirements for physics and chemistry. Some schools require a considerable number of chemistry courses but they are of the "practical" sort rather than a sequence leading to a development of basic theory in the fields of inorganic, qualitative, quantitative, organic, biological and physical chemistry. Several other schools have followed the latter scheme, however.

Proposition B. "That it is impossible for any person to become proficient in all phases of food technology and therefore it would be better to train students in the basic sciences with perhaps a limited knowledge of their application to food technology, rather than to turn out students with a superficial knowledge of a large number of food industries and operations but lacking in basic training."

Here again the idea seems to have been accepted by practically all of the schools although to varying degrees. In several cases the schools have gone "all out" for an extensive practical training including not only the technology of certain foodstuffs but also their culture. In other cases the application courses are limited to those in the field of general food chemistry and bacteriology.

Proposition C. "That the students' specialized training in the application of these basic science principles to the field of food technology be reserved for periods toward the end of their college training."

Here again there is a considerable variation in the adherence to the proposition by the various schools. Some begin the training in the application phases at the freshman level and continue it throughout the four years. Others have limited it entirely to the junior and senior years.

Proposition D. "That the student acquire some knowledge of the principles of engineering, either in the field of mechanical engineering or in the field of chemical engineering."

Nearly all of these schools have included some engineering courses in the curriculum although there are several notable exceptions. Most of them require one or two courses, generally in the field of chemical and/or refrigeration engineering.

Proposition E. "That the student acquire training in subject matter auxiliary to the scientific training but very necessary to his proper functioning in industry; such as, law, business, accounting, statistics, personnel relationships, English, report writing, record keeping, geographical agriculture."

This proposition is so general that it is difficult to make a statement regarding the degree of conformity to it among schools. However, most of them do require a considerable amount of course work in the humanities, and in addition, several require courses in law, accounting, personnel relationship, etc. There seems to be two schools of thought in this connection; those who require only the basic humanities courses (sociology, psychology, economics, etc.) and others who require specific courses in business administration.

Proposition F. "That it is probably not desirable for all students to receive the same training. Some might specialize in the sanitary aspects of food technology, others in the biochemical, physical, organic, or the engineering, but all should have such a knowledge of the field as a whole as to enable them to understand the literature and language of the whole field."

Because of the fact that several different kinds of colleges and universities are offering work in food technology it makes it rather obvious that the objectives of this proposition will be achieved as it applies to graduates from different schools. In addition some schools have provided a number of options in their curriculum so that students may specialize in such diverse phases of food technology as may be represented by: agriculture, home economics, and biological science.

Proposition G. "That during summer vacations a student work in food processing plants or perhaps drop out during his college course to gain a year of practical experience in a processing plant."

Practically all of the schools highly recommend or make it mandatory that some apprenticeship be served during the four years of collegiate work. Summer is mentioned most generally as the desirable time for accomplishing this objective.

Proposition H. "That probably five years of college work will be required."

The desirability of a five year collegiate program is brought out in several cases. At least two schools have specific five year programs and through it make possible the acquisition of both the B.S. and M.S. degrees after the successful completion of the four and five year programs respectively. In addition, several schools have established conventional graduate programs in food technology, designed for students desiring to engage in food research. These programs lead to the acquisition of M.S. and Ph.D. degrees.

Other curricula which seemed to bear directly on the subject under discussion included those in dairy industry, foods and nutrition and, to a lesser degree, those in the plant industries (horticulture, agronomy, farm crops, etc.) and in the animal industries (animal husbandry, poultry husbandry, dairy husbandry, etc.). While in

some schools these curricula have been coordinated into an all-college food technology curriculum, in many other cases they have not. It is very evident that the course work in these various curricula can make very important contributions to education in the field of food technology.

The curricula in dairy industry of several schools fulfill most, if not all, of the requirements contained in the above-discussed propositions, the weakness being a lack of diversification commodity-wise. In this respect it is my opinion that some of the dairy industry curricula are equal or superior to several of the regular food technology curricula.

The curricula in foods and nutrition (home economics) contain some valuable course work in those aspects of food which relate specifically to utilization (preparation and serving of foods, testing foods for their functional and organoleptic properties, dietetics and institutional management).

Animal and plant industry curricula also contain valuable course work in food technology which relate to the quality of foods as affected by husbandry and crop production practices. In addition, specific commodity technology is taught in other courses in these curricula under such labels as marketing, processing, canning, etc.

It is worth noting that those schools which have strong curricula in science, agriculture and home economics have an unusual opportunity for well-rounded, all-college food technology curricula. Several such institutions have taken advantage of such an opportunity in this connection and are offering all-college instructional programs in this field.

SUMMARY

In summarizing, it is obvious that there is no uniformity among the curricula in food technology being offered by the various colleges and universities of the country today. This is not surprising, however, since the field is still relatively new and since a number of different kinds of institutions are involved. It is quite natural that a food technology curriculum developed by groups representing such diverse interests as chemistry, chemical engineering, animal husbandry, bacteriology, public health, etc., should turn out to be so different in course content. More uniformity will come only after there is a better understanding among us and a better coordination of effort on the part of the many people interested in developing education in food technology. There will always be differences among institutions. An agricultural college will almost inevitably develop a more commodity-slanted curriculum than will liberal arts and engineering schools. Indeed it alone usually has the commodity specialists with which to do it. Furthermore, the field of food technology is so large and so varied that we should not expect a uniform development in education for it. Indeed, it is doubtful whether or not this would be the best way by which to assure its fullest development.

In closing I should like to make a plea for tolerance and understanding in connection with developing a suitable educational program for food technologists. Our best hope is to continue to meet like this and thereby provide opportunities for raising and discussing issues. Above all we should allow plenty of time for experience to play its most important role in the establishment of "best ways." It is almost certain that 10 or 20 years from now we are certain to have much better judgment about the proper education for the food technologists than we can possibly have today.

Editorial

Food is Fundamental[1]

There have been three major developments in the food industry within the memory of many of our older members. The greater portion of our food supply no longer goes directly from agricultural producing centers to the consumer; it passes in ever increasing quantities through plants that process it and distribute it to our citizens and to the rest of the world. That has been the first development. It would be difficult indeed to conceive of any advanced civilization which did not possess the means of carrying over food surpluses from one season to another, and to utilize broadly the food grown in circumscribed areas.

About the turn of the century, the second major development began, in the form of discoveries in nutrition which have forced a shift in emphasis from mere preservation to conservation. Bacteriological and chemical tests were supplemented by animal feeding experiments for the purpose of determining what losses of precious vitamins and minerals occurred in processing. New discoveries in the laboratory were translated into new manufacturing technics in the plant with such rapidity and success that scientific research has indeed become the successor of Aladdin's lamp. This scrawny youngster of the early nineteen hundreds has become a giant almost within a generation. Nor is its importance measured alone by capital investment and trained personnel but by the universal acceptance of the scientific method.

Whether one feels that the primary purpose of business is to make a profit, or argues that the basic purpose is to provide jobs, all can agree that the food industry has a very heavy responsibility to the public, for food is basic to public health, and upon the importance of public health it is impossible to place too much emphasis.

The third change is of more recent origin. In fact, the Institute of Food Technologists is a result of it. Time was when a flour miller was just a flour miller. Today, he is more than that. With tremendous technological advances in food processing, his industry is no longer one of vertical operation but one of horizontal operations. Recognition by food processors that they can all use the same basic unit operations irrespective of the raw materials with which they start, or the finished goods with which they end, has made diversification possible. Such diversification portends a more profitable industry in good times, and a more depression-proof one in periods of economic stress.

In all of these changes, the food technologist has been heavily involved. The properly equipped member of our profession is indeed a versatile person. He not only must be certain a food is bacteriologically safe, but that all essential nutrients are conserved, undesirable oxidative and enzymatic changes minimized, flavor and eye appeal retained, packaging good, and label claims consistent with fact—all within sound engineering practice, and at a cost the consumer will pay.

Eleven percent of the land areas of the world, a total of 4,000,000,000 acres, will produce food. The fertility of this land depends upon seven inches of top soil. Our global population is 2,000,000,000. This simply means that seven inches of soil overlying two acres of land is the margin which separates each one of us from starvation.

Meanwhile, the world's population is increasing at the rate of 12,500,000 per year. Not only will the pressure to

[1] President's remarks opening the Seventh Annual Food Conference, Boston, Mass., June 2, 1947.

share the two acres intensify, but concomitantly erosion, neglect, and reckless exploitation are fast dissipating the seven inches of top soil. Our margin of safety is growing smaller.

The conservation of natural resources, the reclamation of submarginal land, and the increased production of non-processed foods are not the primary responsibility of the food technologist. But in our preoccupation with the technical details of food processing we must not fail to interest ourselves in the broader aspects of food production, distribution, and use. Our global problem is basically agricultural. We seem to have abandoned isolationism as a national policy, but scientists, by refusing to participate in civic affairs, practice it as an individual philosophy; and society is the poorer for it. The need for applying the scientific method to our social problems was never greater. We need fewer diplomats in striped pants and more men in overalls willing to work.

Before the war, sixty percent of the people of the world did not get enough to eat. Today, more than two-thirds do not. Hungry and undernourished people, fighting to maintain physical existence, are incapable of building a cooperative world based on justice and human dignity. If peace, progress and prosperity are dependent upon adequate nutrition, then you and I are members of the greatest profession on this earth. Truly, food is fundamental.

E. H. Harvey.

Technological Tolerance

Any person attending the annual meetings of the Institute of Food Technologists is immediately impressed by the variety of interests and backgrounds of our membership and the widely differing capacities in which our members serve science and industry. Perhaps this very difference in experience and functions of our Institute's personnel is what is making our organization so sound in its development and what is attracting the conspicuously high quality of membership.

Under such circumstances it is impossible to attend either a meeting of a local section or a session of the national Institute without coming into contact with stimulating personalities and obtaining new interests and information that may be old in other industries but capable of new application in our own plants and laboratories. Each stimulating contact brings interchanges of problems, brings distant scientific horizons into clearer focus, and presents visions of new processes, new equipment, new reactions, and new products —IF—

This IF is dependent on whether we are interested in the activities and problems of others and whether we are tolerant of their problems and interests regardless of how distant they may seem to us.

The Program Chairman of the Institute of Food Technologists has the problem each year of trying to present at the annual meeting a group of technical, professional, and informal sessions that will satisfy some three thousand members, no two of whom have exactly the same ideas, interests, or attitudes. What a task that is, what a difficult project even to initiate, unless he knows that these members are really tolerant, that they thoroughly understand and *remember* that food technology means different things to different people.

The production men in food plants sometimes wonder about the terms and the symbols of the more cloistered

workers in food research, and vice versa, but it is not at all impossible to understand, appreciate, and learn from each other, if all are practising tolerance.

Our efforts to understand and appreciate the problems and the activities of other food technologists should be spurred by realization of our own need for tolerance towards our projects and ideas on the part of our colleagues. As Robert Burns once so aptly stated:

"O wad some Power the giftie gie us
To see oursels as ithers see us!
It wad frae monie a blunder free us,
An' foolish notion"

Just as food technology is a bridge over which proceed the converging basic facts of several sciences to be forged and cast and to emerge as applications in food processes, so tolerance must be the bridge of understanding that makes the Esperanto of food technology, the universal appreciation of the value of what others do and contribute to the same worthy objective.

We believe that the value and the continued success of our Institute in the future will depend in large measure on this technological tolerance. We repeat, with emphasis, that this same tolerance is what has enabled our organization in the past to extend so greatly the scope and the importance of its activities. May this tolerance continue, and as each of us keeps ever in mind how essential our individual tolerance is in this respect, may our tolerance grow and our interests broaden with mutual advantages to our work, our lives, and our profession of food technology.

B. E. Proctor.

New Course in Food Technology

The reader may have been surprised to learn, from the preceding editorial by George F. Stewart, that 16 major educational institutions in the United States offer degree work in food technology. New evidence of the growing demand for advanced instruction in food technology comes frequently now-a-days in the form of an announcement of an addition to the list of universities and colleges in these ranks.

The latest to have completed its plans for a curriculum in food technology is the Agricultural and Mechanical College of Texas, at College Station. Training food technologists will become a new function for that college beginning with the fall semester, 1947. A five-year course will be offered, in which science, engineering, and business will be stressed. A requirement for graduation will be six months experience in approved food processing or food manufacturing plants.

Professor A. V. Moore, of the Dairy Manufactures Division, organizer of the course, upon reading the editorial by Professor Cruess in the January, 1947 number of Food Technology, was impressed by the parallel between the ideas expressed by Professor Cruess and those upon which his new course was designed. Upon reading the editorial by Professor Stewart in this issue, Professor Moore probably was just as forcefully impressed by the fact pointed out therein that a wide variation in ideas is exemplified in the organization of the courses in the various colleges and universities. As Professor Stewart states, however, this non-uniformity is not surprising since the field is relatively new and since a number of different kinds of institutions is involved. He states further that "more uniformity will come only after there is a better understanding among us and a better coordination of effort on the part

of the many people interested in developing education in food technology."

A. and M. College of Texas is to be complimented upon the extent to which its curriculum in food technology fulfills each of the eight propositions advanced in the first report of the I. F. T. Committee on Education and Curricula discussed by Dr. Stewart. Requirements for graduation are mathematics through calculus, nine semesters of chemistry, including inorganic, qualitative, quantitative, organic, physical, and biological chemistry, four semesters of biology, including bacteriology, two semesters of physics, four semesters of engineering, six semesters of English, and studies in business, economics, history, psychology, and geography. The food technology graduate of Texas A. and M. will be well trained.

C. O. Ball.

CAROTENE RETENTION IN CARROTS

A COMPARISON OF STORAGE BY FREEZING PRESERVATION AND STORAGE IN THE ROOT CELLAR [1, 2]

FRANK A. LEE AND WILLIAM T. TAPLEY
New York State Agricultural Experiment Station, Geneva, New York

Considerable interest has been shown in the retention of carotene in vegetables when preserved by freezing. Among the vegetables already investigated are: spinach *(1)*, asparagus *(1, 4)*, broccoli *(1)*, beet greens *(1)*, peas *(1, 2)*, snap beans *(1, 3)*, lima beans *(1, 4)*, and corn *(3)*. The effect of storage on the carotene content of frozen carrots has not been reported. While data exist in the literature *(5, 6)* on the effect of storage in the root cellar on the carotene content of carrots, no information is available comparing the retention of this substance when these two methods of preservation are employed.

Carrots of the Nantes and Chantenay varieties, both important in New York State, were used in this study. Samples were collected at the beginning of September and analyzed for total solids and carotene, and tested for tenderness with the tenderometer *(7)*. They were collected at intervals thereafter until the entire crop of both varieties was harvested on November 5th. On that date, part of the crop was placed in a root cellar, at a temperature of 48° F. The remainder was put through an abrasive peeler, sliced (¼ inch thick), blanched in boiling water for 3 minutes, packaged, and frozen. These packages were stored at —6° F. throughout the experiment. Samples of each variety were removed from the root cellar and from frozen storage at intervals and analyzed for carotene and total solids. In addition, those taken from the root cellar were tested for tenderness.

For the determination of carotene and total solids, it was found that a sample comprising a relatively large number of carrots, that is, fifteen or more, gave the most satisfactory results. These were scraped, cubed, and frozen at —6° F. The cubes were held in glass jars, and the freezing hastened by means of an air blast. The frozen cubes were then ground in a meat grinder in the zero room. It was ascertained beforehand that the results of the carotene determinations made on samples prepared in this manner were identical with those analyses of the samples of the chopped and mixed unfrozen material. However, much more uniformity of results was obtained by the use of the freezing technique. Carotene was run by a diphasic method *(4)*, and moisture by means of the vacuum oven at 70° C. for 48 hours. Tests for tenderness were run as follows: The carrots were scraped, and cut into approximately ¼-inch cubes. The chamber of the tenderometer was filled with these cubes and the readings taken in the usual fashion. This is the same system used when the toughness of peas is being determined. The tenderometer used, however, was especially made by the Food Machinery Corporation of Hoopeston, Illinois, for this work, and was designed for tougher vegetables than would be used in the standard machine. The standard instrument was designed primarily for peas.

The trend of the results of the carotene determinations run at different intervals throughout the growing period is in line with that obtained by Werner *(5)*. The decline in carotene content in the spring is also in line with the results obtained by Werner. By the time the last samples of carrots stored in the root cellar were taken out, both varieties had become soft, and were more or less unfit for food.

---

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 653, December 8, 1945.
[2] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

TABLE 1

Changes in Carotene, Total Solids, and Tenderometer Readings During Growth and Storage, and Carotene Changes During Frozen Storage

(All results expressed on the wet basis)

Date of analysis	Nantes					Chantenay				
	Fresh or stored in root cellar			Frozen storage		Fresh or stored in root cellar			Frozen storage	
	Solids	Carotene	Tenderometer readings *	Solids	Carotene	Solids	Carotene	Tenderometer readings *	Solids	Carotene
	percent	*gamma/g.*		*percent*	*gamma/g.*	*percent*	*gamma/g.*		*percent*	*gamma/g.*
9/4/43	11.62	60	208							
9/10/43	9.91	60	217			11.61	88	198		
9/16/43	12.28	75	198			11.04	75	192		
10/7/43	12.28	86.3	203			14.07	116.3	196		
10/21/43	11.47	96	210			12.48	127.8	216		
†11/5/43	11.66	100.5	232	9.49	96.3	13.14	130.5	221	9.05	129.5
12/6/43	12.17	112.5	253	9.74	104.0	12.09	140.3	228	8.69	122.7
1/7/44	11.32	114.3	243	9.56	109.3	11.17	150.0	226	8.44	116.3
3/14/44	10.43	96.5	245	9.43	112.0	10.41	121.5	217	8.60	115.0
4/6/44	9.25	97.5	230	9.79	96.5	10.41	120.0	202	8.70	118.0
6/24/44	8.56	82.5	209	8.86	75.0	8.10	100.5	204	8.24	92.5
12/24/44				9.95	102.5				8.67	93.9

* In pounds of shearing force per square inch.

† Harvest date. Part of the crop stored in the root cellar, and the remainder frozen as described.

The average initial temperature of the carrots in the root cellar was 48° F. By December this temperature had fallen to 45° F. In January the carrots showed a temperature of 35° F., and by March, a temperature of 38° F. In April this had risen to 39° F.

Results obtained by several experimenters concerning the changes in carotene during storage in root cellars follow. Werner *(5)* stated, "There was no change in carotene content in storage till sprouts started in the late spring." Lemke *(8)* found that carrots stored during the winter of 1939-40 lost dry matter, but the carotene content of them remained unchanged. Langley et al. *(9)* stated that winter storage of carrots for four months in either cool, damp or warm, dry cellars resulted in no deterioration of vitamins A, B, and C. Magruder *(6)* stated that carrots stored at 32° F. retained a higher percentage of their original carotene content than those stored at 50° F.

The tenderometer studies showed surprisingly similar readings throughout the growing season and storage period. Only during the first part of the period of storage were significantly increased readings recorded. These increases, however, were not great. It is interesting that in nearly every case the Nantes variety was slightly tougher than the Chantenay.

The samples held in frozen storage were still in good condition after a year. The carotene content of the Chantenay had dropped to some extent, while that of the Nantes remained almost the same, except for the sample analyzed on June 24th. The low figure on this date may have been the result of a sampling error. Good checks for duplicate runs were obtained.

SUMMARY

1. Both root cellar and frozen storage yield satisfactory products.
2. There is good retention of carotene in carrots preserved by either method.
3. Carrots preserved by freezing are in good condition long after those held in the root cellar have undergone deterioration.
4. Tenderometer readings showed surprisingly similar readings throughout the growing season and storage period.

1. Zscheile, F. P., Beadle, B. W., and Kraybill, H. R. Carotene content of fresh and frozen green vegetables. Food Research, *8*, 299-313 (1943).
2. Stimson, C. R., Tressler, D. K., and Maynard, L. A. Carotene (vitamin A) content of fresh and frosted peas. Food Research *4*, 475-483 (1939).
3. Zimmerman, W. I., Tressler, D. K., and Maynard, Leonard A. Determination of carotene in fresh and frozen vegetables. I. Carotene content of green snap beans and sweet corn. Food Research *5*, 93-101 (1940).
4. Zimmerman, William I., Tressler, D. K., and Maynard, L. A. Determination of carotene in fresh and frozen vegetables by an improved method. II. Carotene content of asparagus and green lima beans. Food Research *6*, 57-68 (1941).
5. Werner, H. O. Dry matter, sugar, and carotene content of morphological portions of carrots through the growing and storage season. Proc. Amer. Soc. for Hort. Sci. *38*, 267-272 (1941).
6. Magruder, R. Growing conditions have important effect on beet and carrot pigmentation. Canning Age *22*, 93 (1941).
7. Martin, W. McK. The tenderometer. An apparatus for evaluating tenderness in peas. The Canning Trade *59*, 29, 7-14 (1937).
8. Lemke, M. The quality of storage vegetables. Gartenbauwiss *16*, 129-135 (1941).
9. Langley, Dorothy, Richardson, Jessie, and Andes, Erlene. The effect of storage and canning upon the vitamin content of carrots. Montana Agricultural Experiment Station Bulletin 276, May, 1933.

The authors wish to express their appreciation to the Food Machinery Corporation of Hoopeston, Illinois, for supplying the special tenderometer used in this study.

FLUORESCENCE SPECTRA OF EXTRACTS OF DRIED WHOLE EGG POWDER [1, 2]

JESSE A. PEARCE AND W. A. BRYCE
Division of Applied Biology,
National Research Laboratories, Ottawa, Canada

INTRODUCTION

The fluorescence of saline extracts of defatted egg powder is related to the eating quality *(11)* and increase in the fluorescence value is a good measure of deterioration during storage *(10, 17)*. Further work both here *(7, 8, 18)* and elsewhere *(1, 6, 17)* has led to the belief that the deterioration in egg powder was related to the protein and carbohydrate fractions. Therefore, information about reactions between sugars and proteins was sought.

An excellent description of reactions between sugar and amino acids has been presented by Enders *(2)*. This work suggests a mechanism for such a reaction and indicates that the reaction product contains a five-membered heterocyclic ring composed of four carbon atoms and a nitrogen atom. These reactions have been summarized elsewhere *(9)*.

During previous work, it was noted that a yellow, fluorescing substance was extracted from chloroform defatted egg powder *(7)*. An attempt was made to isolate some of the fluorescing substance, but, before this work had been carried very far, the difficulty of separating and isolating the fluorescing fractions was apparent. Since the substances fluoresced, it was believed that a technique similar to that used to identify carcinogenic substances *(4)* might be applicable. The Coleman photofluorometer was modified and used to make crude estimations of the fluorescence spectra of egg powder extracts.

While some work has been done to show a relation between fluorescence and the component parts of a molecule, little information was available that could be applied to the present problem *(13, chap. xiv)*. Therefore, the fluorescence of a number of chemicals was examined to provide a background of information for work on egg extracts.

The present paper describes the fluorescence spectra of egg powder extracts and compares them to spectra of various chemicals and of the reaction products of various amino acids and sugar-like substances. In addition, absorption spectra of some of the fluorescing materials are described.

MATERIALS AND METHODS

The dried egg products used were materials available from storage studies in progress in the laboratory. Their quality was assessed by the standard fluorescence method *(12)*. The chemicals were either the best available from commercial sources or were purified products obtained from other investigations in these laboratories. Solvents used for the various chemicals, chloroform, alcohol, ether and water, were redistilled in the laboratory. For the extraction of fluorescing material from egg powder the organic solvents were used in the anhydrous state.

The Coleman photofluorometer was modified for use as a "fluorospectrometer" by substituting, for filter PC-1, filters similar to those used in a colour-measuring device *(19)*. A group of nine filters was used to separate the visible portion of the

[1] Issued as Paper No. 162 of the Canadian Committee on Food Preservation and as N. R. C. No. 1431.

[2] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 19, 1946.

spectrum into bands about 30 mμ in width. All results presented here are expressed in terms of the principal wave lengths of these bands. Unfortunately, during a portion of the investigation a faded set of filters was used and no blank correction was made for solvents. However, sufficient reference curves were available to permit conclusions of value.

Since the transmission in the various filters was not of equal intensity, a correction factor was necessary (Table 1). The table also shows that the band with a

TABLE 1

Showing Corrections Necessary in Determination of Fluorescence Spectra of Pyrrole (Fluorescence with Filter PC-1, 60 Photofluometer Units)

Principal wave length, mμ	Fluorescence intensity		Correction for filters	Final reading	Relative intensity
	as read	less blank correction (alcohol)			
412	off scale	.....	.....	.....	.....
444	77.5	72.5	1.14	82.7	57.5
474	28.5	21.5	1.17	25.2	4.6
512	21.0	20.0	1.03	20.6	13.0
542	7.8	7.3	1.04	7.6	5.7
572	1.9	1.9	1.00	1.9	1.7
600	0.2	0.2	1.00	0.2	0.2
630	0	0	1.00	0	0
700	0	0	1.00	0	0

principal wave length of 412 mμ transmitted too much light to permit a reading on the scale: possibly some incident light, since the B-1 filter transmits light up to about 410 mμ *(3)*. Comparison of the transmission curve for filter PC-1 and a fluorescence curve for a pyrrole solution (Fig. 1) indicated that light around 412 mμ was not transmitted to the photocell in the ordinary fluorescence measurement.

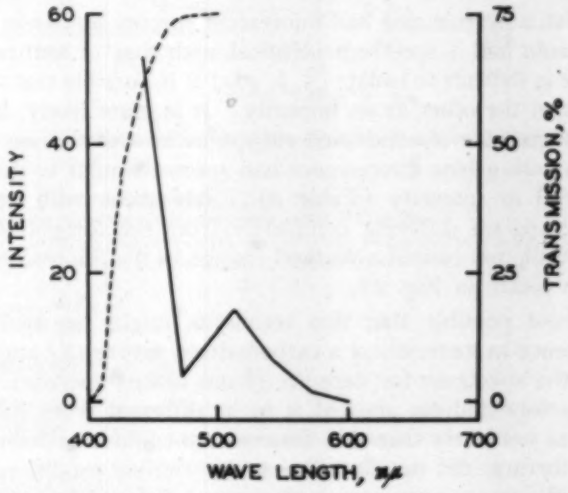


FIG. 1. Ultra-violet transmission of filter PC-1 (dotted line) compared with a portion of the fluorescence spectrum of pyrrole.

To maintain the instrument at the same setting during a determination, it was checked frequently using filters B-1 and PC-1 and standard quinine sulfate (0.2 γ per ml.). Under these conditions, the fluorometer reading was set at 50.

Coleman cuvettes transmitted about 90 percent of the incident light at 360 mμ and were considered satisfactory. All fluorescence readings are given as units on the photofluorometer scale. Fluorescence determined using filter PC-1 was the standard of comparison for all materials studied. To provide fluorescing solutions within the range of the photofluorometer, the solutions were made up to a known fluorescence value rather than to predetermined concentrations.

The absorption curves presented here were determined using a Beckman Quartz Spectrophotometer.

RESULTS

Fluorescence Spectra of Chemicals and Various Reaction Products. The fluorescence spectra of various chemicals and reaction products of sugars and amino acids are given in Figs. 2 and 3 and in Table 2. Substances with negligible fluorescence or no fluorescence are given in Appendix I.

TABLE 2

Fluorescence Spectra of Various Substances, Similar to Pyrrole in This Characteristic. Fluorescence with Filter PC-1, 50-55 (New Filters and Blank Corrections Made)

Substance	Fluorescence intensity passing filter with principal wave length (mμ) of:					
	444	474	512	542	572	600 and higher
Anthracene and carbazole	90.5	0.6	4.1	0	0	0
Sodium salicylate	71.0	2.1	5.1	1.1	0.5	0
Oleic acid	57.4	1.8	10.2	3.7	1.0	0
Thiochrome	52.2	2.3	8.0	1.5	0.5	0
Pyrrole	48.2	3.4	10.0	5.0	1.4	0
Di-cyclopentadiene	41.7	2.5	12.8	4.2	1.5	0
Quinine sulfate at 45° F. and at 80° F.	39.4	3.4	11.3	4.2	1.0	0

Chemicals with a pyrrole ring had fluorescent spectra similar in nature (Fig. 2). However, carbazole had a spectrum identical with that of anthracene (Table 2). Since anthracene is difficult to isolate *(5, p. 492)* it is possible that one of the chemicals used contained the other as an impurity. It is more likely, however, that the spectrum is characteristic of condensed ring structures of this type. A number of other substances with a blue fluorescence had spectra similar to that of pyrrole, but the bands differed in intensity (Table 2). Substances with other than a blue fluorescence had spectra differing completely from the foregoing (Fig. 2). The addition of a metallic ion caused a marked change in the fluorescence spectra (oleic acid and sodium oleate in Fig. 2).

It was believed possible that this technique might be used to differentiate between fluorescence in materials of a carbohydrate nature *(8)* and other chemicals. Comparison of the spectrum for caramel (from heated sucrose) with spectra for pyrrole and dicyclopentadiene showed it to be different from either of these two materials. It was not likely that this fluorescence could be attributed to furan-like materials since furfural did not fluoresce under similar conditions (Appendix I). In addition, the fluorescence spectrum of caramel differed from the spectra of egg powder extracts (cf. Fig. 7).

While many amino acids do not fluoresce *(14)*, this examination showed that tryptophane does fluoresce and has a spectrum similar to that of pyrrole (Fig. 2). However, the limited solubility of this substance prevented any examination at high fluorescence values.

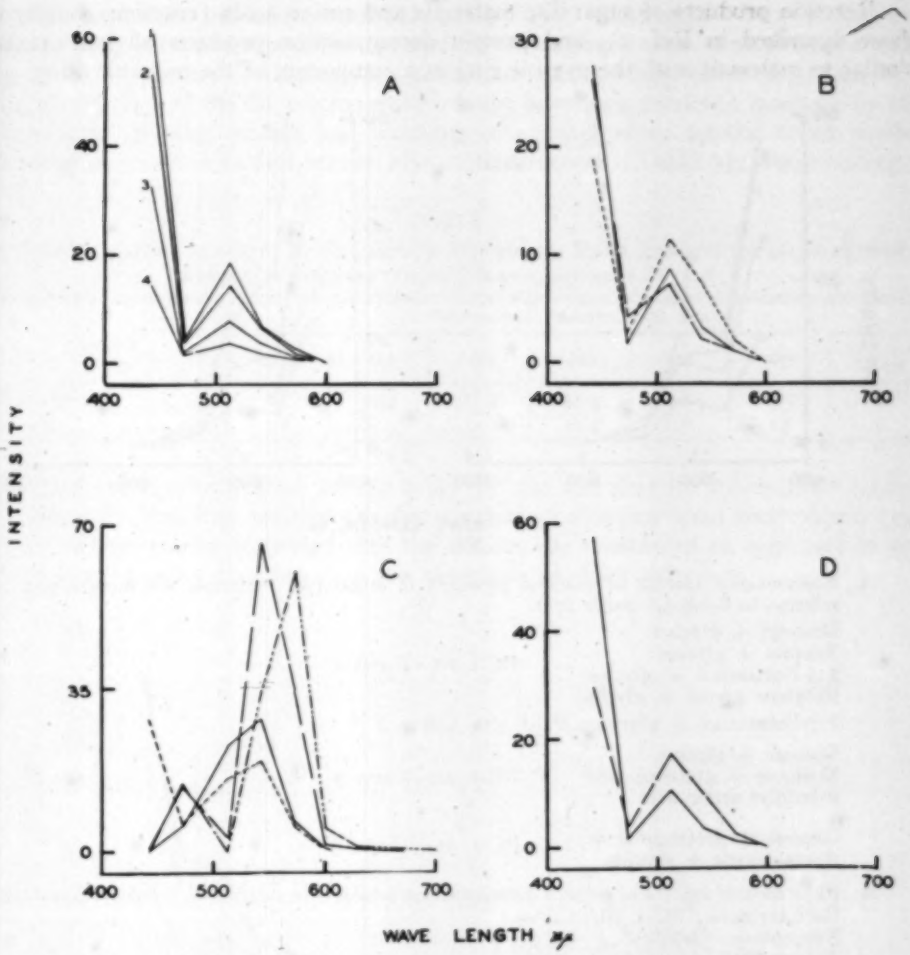


FIG. 2. Fluorescence spectra of various chemicals (all curves determined using new filters and with a blank correction).

A. 1. Nicotine; Fluorescence with PC-1, 70.
2. Pyrrole and nicotine; Fluorescence with PC-1, 60.
3. Pyrrole, nicotine and β-indolyl acetic acid; Fluorescence with PC-1. 40.
4. Pyrrole, nicotine and tryptophane; Fluorescence with PC-1, 20.

B. Pyrrole: ————
Di-cyclopentadiene: — — —
Caramel: - - - - -
Fluorescence with PC-1, 34.5.

C. Sodium fluorescein: ————
Acridine orange: - - - - -
Eosin blue: — — —
Acridine red } — - - — - - —
Rhodamin G }
Fluorescence with PC-1, 50-55.

D. Oleic acid: ————
Sodium oleate: ————
Fluorescence with PC-1, 55.

Reaction products of sugar-like materials and amino acids (reactions similar to those described in Ref. 2), and protein decomposition products all had spectra similar to materials with the pyrrole ring as a component of the molecule (Fig. 3).

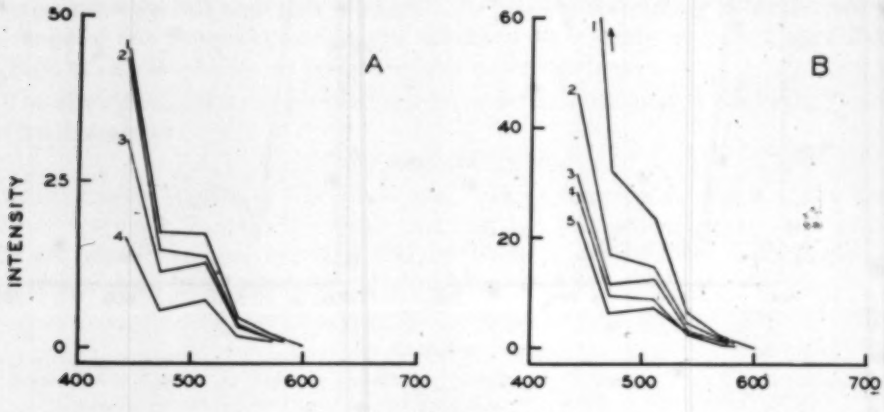


FIG. 3.

A. Fluorescence spectra of reaction products of sugar-like materials and amino acids in relation to β-indolyl acetic acid.

Diacetyl + glycine
Acetoin + glycine
1:3-Butanediol + glycine
Ethylene glycol + glycine
} PC-1, 60,—Curve 1

2:3-Butanediol + glycine; PC-1, 53,—Curve 2

Glucose + glycine
Mannose + glutamic acid
β-Indolyl acetic acid
} PC-1, 40,—Curve 3

Glucose + glutamic acid
Acetaldehyde + glycine
} PC-1, 19,—Curve 4

B. Fluorescence spectra of protein decomposition products in relation to β-indolyl acetic acid.

Bactotryptone; PC-1, 96,—Curve 1
Neopeptone
Thiopeptone
} PC-1, 58,—Curve 2
β-Indolyl acetic acid: PC-1, 40,—Curve 3
Bactopeptone; PC-1, 32,—Curve 4
Proteose peptone; PC-1, 23,—Curve 5

(All curves determined using old filters without a blank correction.)

Fluorescence Spectra of Egg Powder Extracts. The fluorescence spectra of egg powder extracts were similar to those of substances containing the pyrrole ring (Fig. 4). Furthermore, there were at least two differentially soluble materials of this structure: one (in yolk) was more highly fluorescent in alcohol; while the other (in white) was more highly fluorescent in potassium chloride solution (Fig. 4).

It had been observed during previous work on ethanol extracts of chloroform defatted egg powder that the weight of ethanol-extractable material increased as the quality of the powder decreased (unpublished results during work described in 7). Since it was now certain that there was more than one fluorescing substance, it was decided to confine this work to the fluorescing materials in an alcohol extract of chloroform defatted egg powder.

The possibility that the fluorescing substance was tryptophane only was dismissed since this compound is so difficult to dissolve and since the greatest quantities of alcohol-soluble material were extracted from the poorest powders.

The separation procedure used is shown in Fig. 5. Cooling to —112° F. followed by warming to room temperature reduced the fluorescence value of an alcohol extract by about 25 percent. Although no precipitate was evident, either a portion or a specific fraction of the fluorescing material may have been rendered insoluble by this treatment. Similar cooling and warming procedures when applied to an alcohol solution of nicotine caused an increase in fluorescence (Table 3), while cooling a

TABLE 3

Effect of Cooling to —112° F. Followed by Warming to Room Temperature on an Alcohol Solution of Nicotine (Initial Fluorescence with PC-1, 61)

Sample	Fluorescence intensity with filters:						
	PC-1	444	474	512	542	572	600 and higher
Untreated	61	41.3	11.4	15.4	6.8	1.5	0
Cooled	76	61.8	4.0	18.4	8.9	1.5	0

standard solution of quinine sulfate to 45° F. did not alter its fluorescence spectra (Table 2). Freezing reduced the fluorescence of a serum from fresh liquid eggs *(15)*. These results indicated that the fluorescing substances in eggs and in egg powder were more complex than the chemicals used for reference.

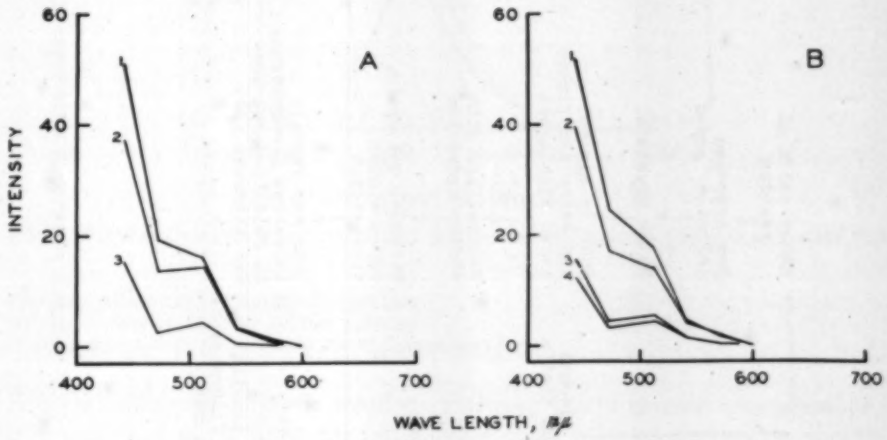


FIG. 4.

A. Fluorescence spectra of potassium chloride solution extracts of defatted egg powders of different quality.
   1. Fluorescence, 68 (identical with curve for nicotine at same fluorescence with filter PC-1).
   2. Fluorescence, 50.
   3. Fluorescence, 13.

B. Fluorescence spectra of potassium chloride solution and ethyl alcohol (95%) extracts of defatted dried white and yolk.
   1. White extracted with potassium chloride solution.
   2. Yolk extracted with alcohol.
   3. Yolk extracted with potassium chloride (identical with curve for tryptophane at same fluorescence value with filter PC-1).
   4. White extracted with alcohol.

(All curves determined using old filters without a blank correction.)

The fluorescence of a solution of the hydrogen chloride precipitate shown in Fig. 5 was destroyed by neutralization. This may explain the high fluorescence

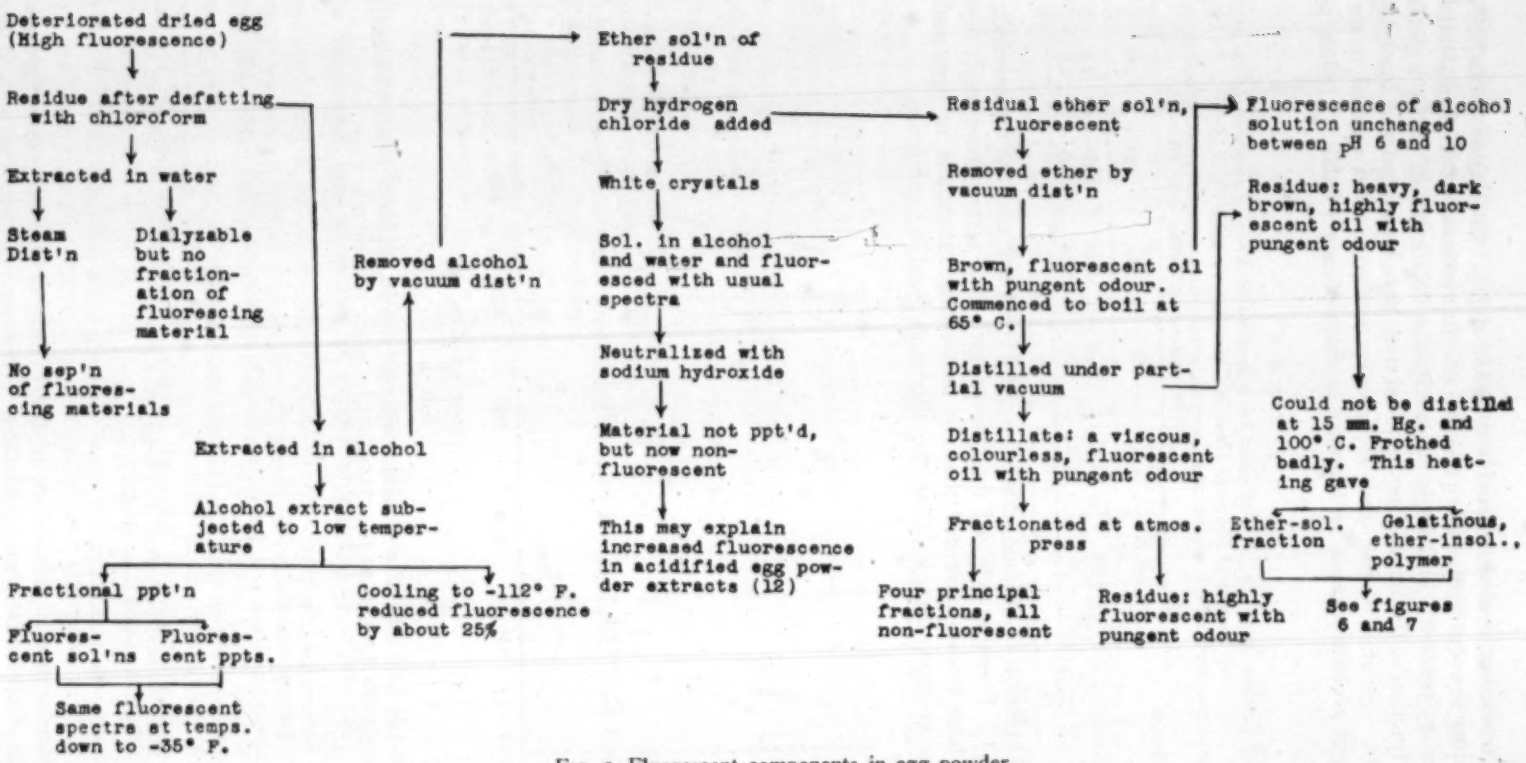

Deteriorated dried egg (High fluorescence)
Residue after defatting with chloroform
Extracted in water
Steam Dist'n
Dialyzable but no fraction-ation of fluorescing material
No sep'n of fluores-cing materials
Extracted in alcohol
Alcohol extract sub-jected to low temper-ature
Fractional ppt'n
Fluores-cent sol'ns
Fluores-cent ppts.
Same fluorescent spectra at temps. down to -35° F.
Cooling to -112° F. reduced fluorescence by about 25%
Removed alcohol by vacuum dist'n
Ether sol'n of residue
Dry hydrogen chloride added
White crystals
Sol. in alcohol and water and fluor-esced with usual spectra
Neutralized with sodium hydroxide
Material not ppt'd, but now non-fluorescent
This may explain increased fluorescence in acidified egg pow-der extracts (12)
Residual ether sol'n, fluorescent
Removed ether by vacuum dist'n
Brown, fluorescent oil with pungent odour. Commenced to boil at 65° C.
Distilled under part-ial vacuum
Distillate: a viscous, colourless, fluorescent oil with pungent odour
Fractionated at atmos. press
Four principal fractions, all non-fluorescent
Residue: highly fluorescent with pungent odour
Fluorescence of alcohol solution unchanged between pH 6 and 10
Residue: heavy, dark brown, highly fluor-escent oil with pungent odour
Could not be distilled at 15 mm. Hg. and 100° C. Frothed badly. This heat-ing gave
Ether-sol. fraction
Gelatinous, ether-insol., polymer
See figures 6 and 7

FIG. 5. Fluorescent components in egg powder.

values previously noted for acidified solutions of the fluorescing material *(12)*. Since the material in the residual ether solution also fluoresced, and since an alcohol solution of these materials had a constant fluorescence at pH 6 to 10 (Fig. 5), it was now believed that the alcohol extract contained at least two fluorescing substances.

The heavy, dark brown, residual oil (Fig. 5) gave two fractions following a futile attempt to distill the material under vacuum. One of these fractions was soluble in ether and insoluble in water while the other was ether-insoluble but water-soluble. The fluorescence spectra of solutions of these two materials were similar to that of pyrrole (Fig. 6).

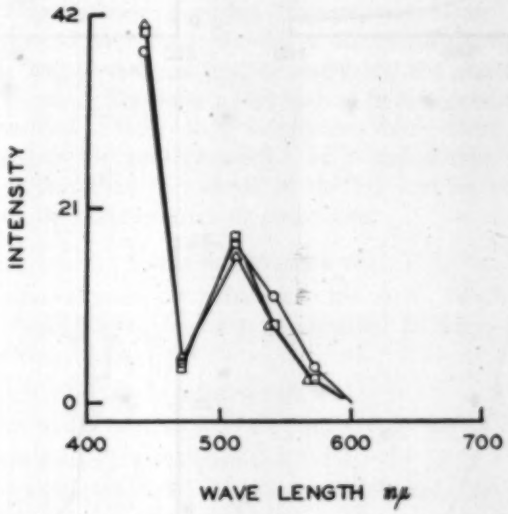


FIG. 6. Fluorescence spectra of extracts of egg powder and pyrrole (fluorescence with PC-1, 52).
○ pyrrole in ether.
□ ether solution of ether-soluble portion.
△ water solution of ether-soluble polymer.
(Using new filters but without blank corrections.)

Absorption curves on these solutions indicated that a greater concentration of pyrrole was required to attain the same fluorescence value as that of the materials causing fluorescence in egg powder (Fig. 7). This was a further indication of the complexity of the fluorescing materials in egg powder. A more dilute solution of pyrrole had absorption bands between 254 and 278 mμ, and between 284 and 310 mμ. Although the absorption peaks for the water solution of the gelatinous, ether-insoluble polymer were lower than those of pyrrole, the bands were identical. Absorption peaks at 268 and 280 mμ and at 305 and 315 mμ were observed in other examinations of egg powder extracts *(6)*. In the present study, the ether-soluble material had absorption peaks at 268 and 280 mμ only. All fluorescing extracts examined by absorption studies varied appreciably from the absorption at 360 mμ observed for thiochrome *(16, p. 120)* which has a blue fluorescence similar to that of pyrrole.

The water-soluble substance may be a polymer resulting from the heat applied to the residual fluorescent oil during the attempted distillation or it may be a third fluorescing component (heat coagulable) of the alcohol extract of defatted egg powders.

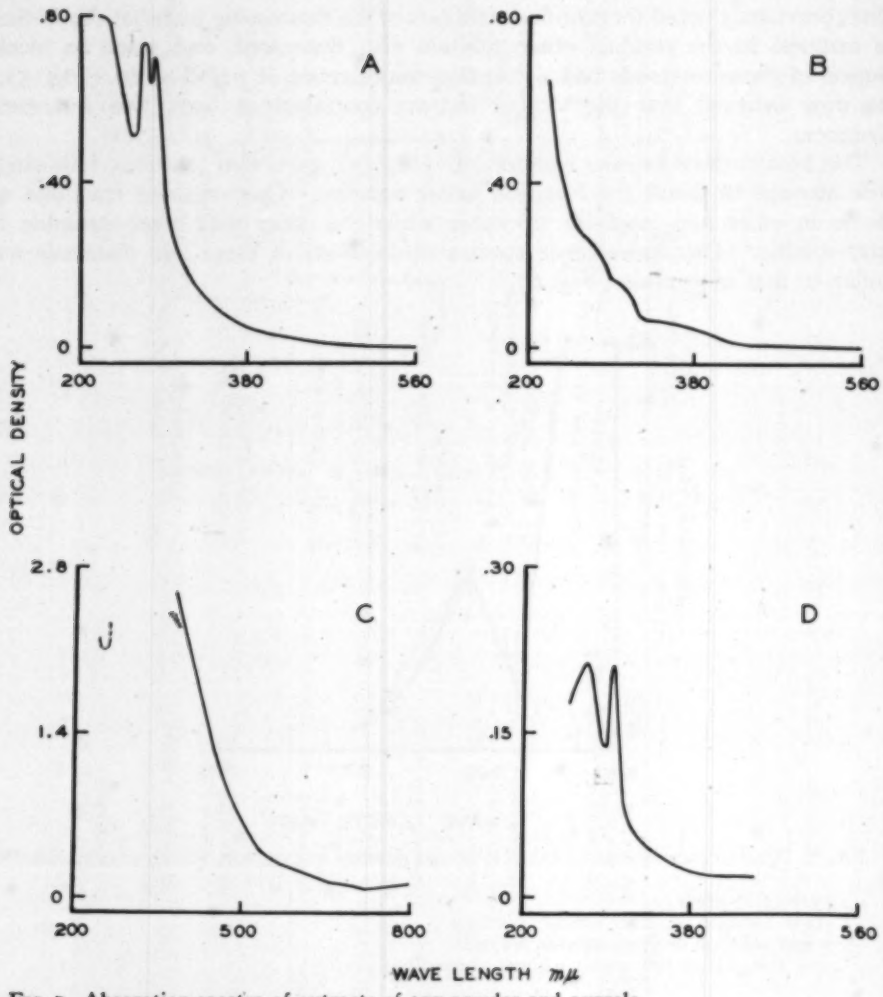


FIG. 7. Absorption spectra of extracts of egg powder and pyrrole.

A. Ether solution of ether-soluble portion.
B. Water solution of ether-insoluble portion.
C. Ether solution of pyrrole at same fluorescence value as A and B (with PC-1, 52).
D. Alcohol solution of pyrrole, more dilute than C.

SUMMARY AND EXTENSION

The Coleman photofluorometer was modified for use as a "fluorospectrometer" by substituting for filter PC-1 nine filters which permitted separation of the visible portion of the spectrum into bands about 30 mμ in width. Using this device, pyrrole, nicotine, β-indolyl acetic acid, and tryptophane were observed to have similar spectra. These spectra differed slightly from those of other substances with a blue fluorescence and differed markedly from substances with red and green fluorescence. Protein degradation products and the reaction products of sugar-like substances and amino acids also had fluorescence spectra similar to pyrrole.

At least three fluorescing substances of different character and possibly a fourth were detected in extracts of poor quality egg powder. One, present in dried white, was highly fluorescent in potassium chloride solution. Fluorescent material in yolk

was soluble in alcohol. Alcohol extracts of defatted whole egg powder gave a material that fluoresced only when in acid solution, and an ether-soluble but water-insoluble material. In addition, an ether-insoluble but water-soluble polymer was obtained as a result of an attempt to distill the ether-soluble fraction under reduced pressure. All fluorescing materials had spectra almost identical with that of pyrrole and the polymer showed absorption bands similar to pyrrole.

These results pointed to pyrrole-like substances as some of the degradation products in dried egg powder and supported the evidence that the sugar-protein reaction occurs in this product during its deterioration.

While the fluorescence spectra described are crude, they were useful in this work on dried egg powder. Since a similar technique has been used to detect carcinogenic substances, a more accurate "fluorospectrometer" would be generally desirable. The proposed instrument should be capable of providing monochromatic incident light from 200 to 600 mμ and of analyzing the emitted fluorescent light between 200 and 800 mμ. The instrument should be designed to determine spectra at definite concentrations of fluorescing substances rather than at a fixed maximum fluorescence, as used in the present work. It is hoped that such an instrument, costing hundreds, rather than thousands of dollars, can be produced in the near future either in our own laboratories or elsewhere.

ACKNOWLEDGMENTS

The authors wish to express their thanks to Dr. A. C. Neish, Biochemist, Industrial Utilization Investigations, Division of Applied Biology, who prepared some of the chemicals used.

REFERENCES

1. Bate-Smith, E. C., and Hawthorne, J. R. J. Soc. Chem. Ind., *64*, 297-302 (1945).
2. Enders, C. Kolloid-Zeit., *85*, 74-87 (1938).
3. Fryd, C. F. M., and Hanson, S. W. F. J. Soc. Chem. Ind., *63*, 3-6 (1944).
4. Hieger, I. Biochem. J., *24*, 505-511 (1930).
5. Kipping, F. S., and Kipping, F. B. Perkin and Kipping's Organic Chemistry. J. B. Lippincott Co., Philadelphia (1932).
6. Olcott, H. S., Dutton, H. J., and Edwards, B. G. Ind. Eng. Chem.,Ind. Ed., *37*, 1119-1126 (1945).
7. Pearce, J. A. Can. J. Research, D, *21*, 98-107 (1943).
8. Pearce, J. A. Can. J. Research, F, *22*, 87-95 (1944).
9. Pearce, J. A . Food in Canada, 5, No. 11, 24-35 (1945).
10. Pearce, J. A., Reid, M., and Cook, W. H. Can. J. Research, F, *24*, 39-46 (1946) .
11. Pearce, J. A., and Thistle, M. W. Can. J. Research, D, *20*, 276-282 (1942).
12. Pearce, J. A., Thistle, M. W., and Reid, M. Can. J. Research, D, *21*, 341-347 (1943).
13. Radley, J. A., and Grant, J. Fluorescence Analysis in Ultra-Violet Light, Chapman and Hall Ltd., London (1939).
14. Reeder, W., and Nelson, V. E. Proc. Soc. Exp. Biol. Med., *45*, 792-794 (1940).
15. Reid, M. Can. J. Research, F, *24*, 130-135 (1946).
16. Rosenberg, H. R. Chemistry and Physiology of the Vitamins. Interscience Publishers, Inc., New York (1942).
17. Stewart, G. F., Best, L. R., and Lowe, B. Proc. Inst. Food Tech., 1943, 77.
18. White, W. H., and Thistle, M. W. Can. J. Research, D, *21*, 194-202 (1943).
19. Woodcock, A. H. Can. J. Research, D, *21*, 90-97 (1943).

APPENDIX I

Non-Fluorescing Substances and Substances with Negligible Fluorescence (Filters B-1 and PC-1)

Non-fluorescing	Negligible fluorescence
o-p-Hydroxybenzeneazo-p-nitrobenzene	Butadiene
Colchicine	Thiophene
4,5-Dimethyl-2-mercapto-thiazole	Chlorophyll
2-Methyl-1,4-napthoquinone	Arginine
Pyridine	Proline
Nicotinic acid	
Ethylene diamine	
Creatine	
Creatinine	
Sodium barbitone	
2-Thion-5,5-dimethyl-oxazolidine	
4-Phenyl-2-thion-thiazoline	
1,4-Thiazane-4-acetic acid	
2-Acetamino-thiazole	
Antipyrene	
Maleic anhydride	
Furfural	
Glycine	
Glutamic acid	
Methionine	
Valine	
Phenylalanine	
Histidine	
Threonine	
Lysine	
Leucine	

THE ACTIVITY OF CERTAIN CATIONIC GERMICIDES[1]

G. J. HUCKER, R. F. BROOKS, DOROTHEA METCALF
AND WM. VAN ESELTINE
New York State Agricultural Experiment Station, Geneva, New York

An ever-expanding group of cationic quaternary ammonium compounds is being made available as potential germicides. Although known and studied as germicides for some time these compounds are receiving particular attention due to an increased interest in industrial sanitation problems, particularly in the field of food processing and dispensing. These germicides are referred to under a variety of designations, *viz.*, cationic germicides, quaternary ammonium compounds, surface active sterilizing agents and by certain groups as quaternary detergents. Although possessing certain detergent and emulsifying properties the scope of the present discussion includes primarily a study of the germicidal properties.

COMPOUNDS STUDIED

A series of 13 compounds (Table 1) was included in the investigation to represent as wide variation as possible in the chemical constitution of the type of germicide. These compounds are all available through regular commercial channels under a variety of trade names. It can be readily appreciated that a wide variety of cationic germicides will eventually be made available for industrial use as the possibility of variation in chemical structure with the quaternary ammonium central characteristic offers a wide scope of compounds.

In general, these compounds are relatively odorless, colorless, tasteless, and not affected by light and only by extremes of temperature. Certain compounds have a slight "cocoanut" flavor and odor in high concentrations but in dilutions commonly recommended such flavor and odors are not readily discernible. All are water soluble in the concentrations necessary for effective germicidal use.

The use of these germicides as compounding mixtures at the moment is limited, due to noncompatability with soaps, many phosphates and all compounds anionic in nature. For this reason the study of the germicidal activities of the compounds must be carried out *per se* and not in mixture with compounds generally employed as cleaning agents or detergents.

METHODS

The following cultures were used as test organisms: (1) *Escherichia coli*, a heat resistant strain from the National Institute of Health, (2) *Aerobacter aerogenes* from the American Type Culture Collection, (3) *Aerobacter aerogenes*, a capsulated (slimy) strain found in paper mills and isolated by J. R. Sanborn, (4) *Micrococcus aureus*, isolated from drainage in a wound of a University of Rochester hospital patient, by C. M. Carpenter, (5) *Streptococcus cremoris*, cheese starter organisms from J. M. Sherman, (6) *Bacillus subtilis*, from American Type Culture Collection, (7) M-23, mesophilic flat sour strain isolated from beets, by the laboratory of the National Canners' Association, (8) No. 1518, facultative thermophilic flat sour strain isolated from peas, by the laboratories of the National Canners' Association, (9) No. 1503, obligate thermophilic flat sour strain isolated from corn, by the laboratories of the National Canners' Association.

The non-spore-bearing cultures were grown in 9 cc. of broth (tryptone 5 g., glucose 1 g., bacto-beef extract 3 g., distilled water 1 liter). Only 24 hour subcul-

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 19, 1946.

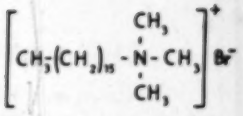
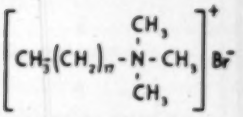
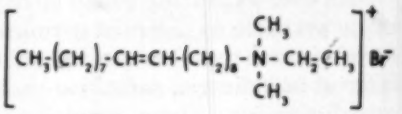
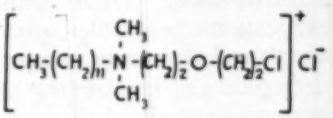
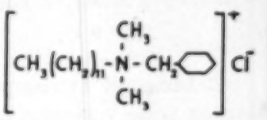
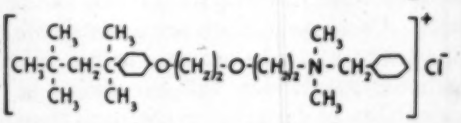
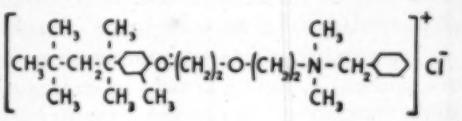
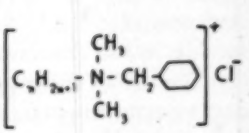
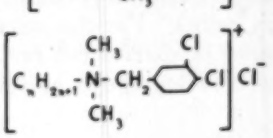
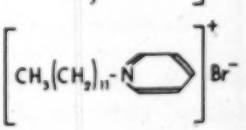
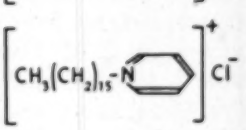
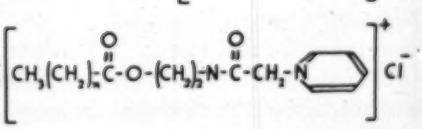
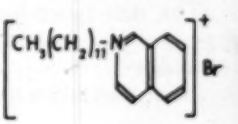
Reference	Compound	
C	**C.T.A.B., CETAVLON:** CETYLTRIMETHYLAMMONIUM BROMIDE	
M	**PRODUCT QB:** STEARLTRIMETHYLAMMONIUM BROMIDE	
N	**ONYXIDE, QUARTOL:** OLEYLDIMETHYLETHYLAMMONIUM BROMIDE	
E	**ISOTHAN OX:** LAURYLDIMETHYLCHLORETHOXYETHYL-AMMONIUM CHLORIDE	
H	**NOPCO QCL:** LAURYLDIMETHYLBENZYLAMMONIUM CHLORIDE	
D	**HYAMINE 1622, POLYMINE D, PHEMEROL:** DIISOBUTYLPHENOXYETHOXY-ETHYLDIMETHYLBENZYLAMMONIUM CHLORIDE	
B	**HYAMINE 10X:** DIISOBUTYLCRESOXYETHOXY-ETHYLDIMETHYLBENZYLAMMONIUM CHLORIDE	
G	**B.T.C., ROCCAL, ZEPHIRAN:** ALKYL (C_8H_{17}-$C_{18}H_{37}$) DIMETHYLBENZYLAMMONIUM CHLORIDES	
A	**TETROSAN:** ALKYL (C_8H_{17}-$C_{18}H_{37}$) DIMETHYL 3,4-DICHLOROBENZYL-AMMONIUM CHLORIDES	
J	**ISOTHAN Q4:** LAURYLPYRIDINIUM BROMIDE	
L	**CEEPRYN:** CETYLPYRIDINIUM CHLORIDE	
K	**EMULSEPT:** N (HIGHER ACYL ESTERS OF COLAMINO FORMYLMETHYL) PYRIDINIUM CHLORIDE	
F	**ISOTHAN Q15:** LAURYLISOQUINOLINIUM BROMIDE	

TABLE 1

The Cationic Germicides Studied

tures of 24 hour cultures were used in germicide tests, and at least three successive transfers (at 24 hour intervals) were made prior to each test.

The spore-forming types were grown on slants (medium similar to above but containing additional 15 g. Bacto agar) in 6 oz. flat bottles. The slants were inoculated by washing the surface with a 24-hour culture and incubated for one week. The bottles containing the cultures were then held at 35° F. until used. To prepare a culture for the germicidal tests, 120 cc. of a tryptone, glucose-beef extract broth were added to the slant and the bottle shaken to suspend all growth. Nine cubic centimeter amounts of the suspended culture were transferred to sterile tubes and boiled for six minutes and quickly chilled.

The cultures of both spore-forming and non-spore-forming organisms were suspended in 9 cc. amounts of broth for the germicide test. By plate counts and comparable nephelometer observations the broth suspensions were standardized to approximately 500,000,000 organisms per cc.

The routine test procedure included the use of 1 cc. of germicide solution of ten times the desired final concentration added to the culture suspension and shaken. This method of adding a smaller amount of germicide to a larger amount of culture was preferred to the phenol coefficient method of the Food and Drug Administration in which a smaller amount of culture is added to a larger volume of germicide. It should be noted that this procedure constitutes a more severe test of germicidal ability than the corollary of adding small amounts of cultures to large amounts of germicide as followed in the phenol coefficient procedure. Results by this method appeared to show fewer discrepancies ("skips") and were more capable of reproduction than results obtained by the Food and Drug Administration Method for phenol coefficient.

In this connection it should be indicated that a need for precise laboratory evaluation procedures is indicated. There is doubt that the adoption of the standard phenol coefficient procedure will eventually prove successful for cationic germicides. Further information on the basic action of the cationics on organisms may indicate that the killing action is not similar in nature to phenol and thus a new basic evaluating procedure may be required.

ACTION OF CATIONIC GERMICIDES ON METALS

To study the possible corrosive effect of cationic germicides on metals commonly used in foods and dairy processing plants, the following metals were secured: nickel, monel, inconel, three grades of tin (1.5# hot dipped, 1.25# hot dipped and 0.5# electro tin plate), aluminum alloy (2S-½H, 3S-½H, 3A-½H, 61S-H), red brass, 30 percent cupro nickel, phosphorus deoxidized copper, tinned copper, three grades of stainless steel (No. 302: 71.84% Fe, 0.11% C, 18.97% Cr, 9.08% Ni; No. 316: 66.21% Fe, 0.07% C, 17.65% Cr, 13.83% Ni, 2.24% Mo.; No. 430B: 82.26% Fe, 0.06% C, 18.24% Cr, 0.21% Ni, 0.23% Al), Mg.-Mn.-Zn.-Al. alloy (93.8% Mg, 0.2% Mn, 3.0% Zn, 3.0% Al), and Mg.-Mn. alloy (98.5% Mg, 1.5% Mn.).

Strips 1" x 4" were immersed 3 inches in 200 cc. of a 1:5,000 dilution of germicide. The germicide was renewed each twenty-four hours with the total exposure of the metal to the germicide lasting approximately twenty-one days.

Three series of these nineteen metals were used: a control series immersed in distilled water, a second series immersed in germicide A and a third in germicide D.

A general survey of the results indicates that neither germicide D nor A when allowed to come in contact with these test metal strips for the test period showed any appreciable effect on the metals, with certain minor exceptions. In these instances,

particularly in the case of hot dipped tin, rusting at the edges of the strips was noted. This was due to the contact of the germicide and water on the base metal at the edges of the strips not protected by the tin coating. In those cases in which tinned copper was studied small pitted spots were found after exposure to the germicide as well as in the water control. Again this was probably due to breaks and abrasions in the tin coating.

In the case of the various magnesium alloys in which the yellow color was present on the original test strips as a result of the pickle process, a slight action was noted as the color was removed by both the germicides and the water control.

It should be concluded that the cationic germicides as represented by germicides A and D probably have little, if any corrosive effect on those metals and alloys commonly used in the fabrication of dairy and food processing equipment.

EFFECT OF METALS ON GERMICIDAL ACTIVITY OF CATIONIC GERMICIDES

In those instances in which the base metal was coated with tin or in which the magnesium alloy had a "pickled" coat a slight corrosion may be indicated due to the effect of the cationic germicide on the base metal. Some materials might be released which, in turn, would reduce the germicidal activity of the germicides. To determine the probable effect of the metal on the effectiveness of the germicides, six metals were selected (nickel, tin, 1.25# and 1.50# hot dipped and 0.5# electrolytic tin plate, Mg.-Al.-Zn.-Mn. alloy, and Mg-Mn. alloy), and brought in contact with a 1:600 concentration of germicides A and D. At intervals of two, four, six and twenty-four hours, the concentration of the cationic germicide was determined as well as its germicidal activity against *Escherichia coli.*

The continued contact of germicides A and D (Tables 2 and 3) on these particular metals did not decrease materially either the germicidal activity nor the concentration of the germicide.

In the case of germicide A held in contact with nickel some variation in the germicidal activity was noted after a four-hour exposure. At the beginning of the contact of the germicide with nickel and at the end of a two-hour exposure eight minutes for a 1:6,000 dilution was required to kill completely a twenty-four hour culture of *Escherichia coli.* At the end of four, and up to twenty-four hours, the period of time required for the total killing of *Escherichia coli* was materially reduced. In those instances in which copper may appear in the fabricating alloy as a base metal it might be assumed that certain copper ions may be dissolved from the metal, thus increasing the germicidal activity of the germicide.

It is tentatively concluded that metals commonly used in fabricating food and dairy processing equipment have little or no effect on the germicidal activity of cationic germicides even in direct contact in low dilutions over a period of twenty-four hours.

RELATION OF SUBLETHAL TREATMENTS OF CATIONIC GERMICIDES TO SENSITIVITY OF BACTERIAL CELLS

To study the method by which cationic germicides affect killing of bacterial cells, the action of sublethal doses of these germicides on the sensitivity of such treated cells to the subsequent treatment of cationic germicides was determined. One cc. of germicide K was added to 9 cc. of a twenty-four hour culture of *Escherichia coli* to give a final dilution of 1:20,000. The culture-germicide mixture was held for five minutes and the cells removed by centrifugation. Including the time required for centrifuging, the cells and germicide were in contact approximately twenty minutes. The treated cells were then diluted to 9 cc. with sterile broth and used as a test culture in determining the germicidal activity of germicide B in a dilution of

EFFECT OF METAL ON GERMICIDE (1:600) DURING 24-HOUR EXPOSURE

METALS	GERMICIDE CONCENTRATION DETERMINED BY COLORIMETRIC METHOD					MINUTES REQUIRED TO KILL 24 HR. E.COLI CULTURE (GERMICIDE 1:6000)				
	O HRS.	2	4	6	24	O	2	4	6	24
NICKEL	910	590	570	540	460	8	8	3	7	3
½" ELECTROLYTIC TIN PLATE	710	625	600	640	650	>10	>10	>10	>10	8
1¼" HOT-DIPPED TIN PLATE	640	580	590	580	600	>10	—	9	10	>10
1½" HOT-DIPPED TIN PLATE	650	610	625	540	730	8	>10	7	>10	>10
Mg-Al-Zn ALLOY	640	640	590	625	600	>10	>10	>10	>10	>10
Mg-Mn ALLOY	590	570	625	570	600	>10	>10	>10	>10	>10

TABLE 2

Action of Various Metals on Germicide A

EFFECT OF METAL ON GERMICIDE (1:600) DURING 24-HOUR EXPOSURE

METALS	GERMICIDE CONCENTRATION DETERMINED BY COLORIMETRIC METHOD					MINUTES REQUIRED TO KILL 24 HR. E.COLI CULTURE (GERMICIDE 1:6000)				
	O HRS.	2	4	6	24	O	2	4	6	24
NICKEL	500	500	500	510	510	5	8	10	5	5
½" ELECTROLYTIC TIN PLATE	560	580	560	570	580	10	>10	>10	>10	7
1¼" HOT-DIPPED TIN PLATE	470	560	550	590	550	>10	—	6	>10	7
1½" HOT-DIPPED TIN PLATE	540	540	560	540	580	>10	9	8	10	10
Mg-Al-Zn ALLOY	580	610	600	540	550	>10	>10	>10	>10	>10
Mg-Mn ALLOY	580	580	590	590	590	>10	>10	>10	>10	>10

TABLE 3

Action of Various Metals on Germicide D

1:6,000. As a control, the activity of germicide B in a dilution of 1:6,000 was determined with an untreated culture of *Escherichia coli.*

It is indicated that under the conditions used germicide K was not effective from the standpoint of total killing in dilutions of 1:20,000 even after thirty minutes' exposure. It was found (Table 4) that the sublethal exposure of *Escherichia coli*

TIME IN MINUTES	9cc. 24HR. E. COLI CULTURE + 1cc. GERMICIDE K TO GIVE 1:20000 DILUTION. AFTER 5 MIN. CENTRIFUGED, CELLS DILUTED TO 9cc. WITH STERILE BROTH AND USED AS CULTURE IN TEST AGAINST GERMICIDE B 1:6000	GERMICIDE B AT 1:6000 WITH AN UNTREATED E. COLI CULTURE
1	+	+
2	−	+
3	−	+
4	−	+
5	−	+
6	−	+
7	−	+
8	−	+
9	−	+
10	−	+

TABLE 4

Effect of Sublethal Treatment with Cationic on Resistance of Escherichia coli

cells to a cationic germicide partially inactivated the cells or that the cell is partially covered by molecules of a sublethal dosage of the germicide. The cells treated with a sublethal dose of germicide K were more sensitive to germicide B than untreated cells. Germicide B in the dilution of 1:6,000 totally kills cells in two minutes which had been previously treated or sensitized with sublethal dosage of germicide K, while similar cells untreated resisted a dilution of 1:6,000 of germicide B for 10 minutes.

It is to be assumed from these observations that the action of the cationic germicides may be physical in nature in contrast to the action of phenols and chlorine compounds. These results indicate that further studies may be necessary to determine if methods can be devised to sensitize cells by compounds other than cationics if such cells are to be eliminated in food and dairy processing equipment by the highest possible dilutions of cationic germicides.

THE EFFECT OF HEAT KILLED CELLS ON THE GERMICIDAL ACTIVITY OF CATIONIC GERMICIDES

To determine if heat killed cells may act differently from cells inactivated by sublethal doses of cationic germicide, a twenty-four hour culture of *Escherichia coli*

was autoclaved to kill completely all cells. One cc. of this heat killed culture was added to 9 cc. of germicide H to give a final dilution of 1:500. After ten minutes exposure of the heat killed culture to this cationic the total volume was adjusted to bring the concentration of the germicide to 1:5,000. The dead cells were removed and this diluted and treated germicide was tested for its germicidal activity in contrast to an untreated control.

TIME IN MINUTES	1cc. HEAT-KILLED E. COLI + 9cc. GERMICIDE TO GIVE 1:500 DILUTION AFTER 10 MIN. ADJUSTED TO 1:5000 FOR TEST.	UNTREATED GERMICIDE AT 1:5000
1	+	+
2	+	+
3	+	−
4	+	+
5	+	−
6	+	+
7	+	−
8	+	−
9	+	−
10	−	−

TABLE 5

Effect of Dead Bacteria Cells on Germicidal Activity of Cationics

It was indicated (Table 5) that the germicidal effectiveness of germicide H was materially reduced, following the contact over a short period with heat killed cells of *Escherichia coli*. This cationic so treated required ten minutes to kill completely a test culture of *Escherichia coli* whereas an untreated control of the same concentration required only five to six minutes for a comparable action.

It is indicated that dead cells of *Escherichia coli* may have the ability to adsorb the germicide ions thus reducing the germicidal activity of the cationic germicides.

THE EFFECT OF CATIONIC GERMICIDES ON THE STAINING REACTIONS OF BACTERIAL CELLS

A series of cultures of *Escherichia coli* and *Streptococcus cremoris* were completely killed with germicides A and H. These cultures, the first Gram negative and the other Gram positive, were stained with methylene blue and safranin before and after the cultures were completely killed by the two germicides. In all instances, when treated with lethal doses of cationic germicides the staining properties of the cultures were not visibly altered.

POSSIBLE RESISTANCE DEVELOPMENT BY *ESCHERICHIA COLI* AFTER REPEATED EXPOSURE TO CATIONIC GERMICIDES

In the use of cationic germicides in the dairy and food industry it is imperative that the germicides retain their effective germicidal activity over long periods of time

and during such periods of usage that germicide-resistant types of organisms are not developed. This is particularly brought into bold relief in those instances in which hot water or heat has been used for sterilizing. Under such conditions, organisms have developed definite heat resistance with the consequence that the thermoduric and thermophilic types have become problems in the food and dairy industry.

Cultures of *Escherichia coli* were treated with 1:6,000 dilution of germicides A and D and a 1:2,000 dilution of germicide N, and transfers made each minute for a total exposure period of ten minutes. The tube in which growth appeared after the longest period of exposure was used as the inoculant culture in the immediate succeeding test. A series of four to six tests was made on each of the three germicides.

In no instance (Tables 6, 7 and 8) using these cationics in dilutions of 1:6,000 or 1:2,000 dilution, was any evidence apparent that cultures of *Escherichia coli* could develop a resistance to cationic germicides. It is realized that these results are tentative as more conclusive evidence should be based on a longer series of sub-

TIME IN MINUTES	GROWTH OF E.COLI AFTER EXPOSURE TO GERMICIDE				
	TEST I	TEST II	TEST III	TEST IV	TEST V
1	+	−	+	+	+
2	+	+	−	+	+
3	−	−	−	−	+
4	+	−	−	−	−
5	+	−	−	−	−
6	−	−	−	−	−
7	−	−	−	−	−

TABLE 6

Relation of Serial Exposure to Resistance of Escherichia coli to Germicide A

TIME IN MINUTES	GROWTH OF E.COLI AFTER EXPOSURE TO GERMICIDE			
	TEST I	TEST II	TEST III	TEST IV
1	+	+	+	+
2	+	+	+	−
3	+	+	−	−
4	+	+	−	−
5	+	+	−	−
6	−	−	+	−
7	−	−	−	−

TABLE 7

Relation of Serial Exposure to Resistance of Escherichia coli to Germicide D

TIME IN MINUTES	GROWTH OF E.COLI AFTER EXPOSURE TO GERMICIDE			
	TEST I	TEST II	TEST III	TEST IV
1	+	+	+	−
2	+	+	+	−
3	+	−	−	−
4	−	−	+	−
5	−	−	−	−
6	−	−	+	−
7	−	−	−	−

TABLE 8

Relation of Serial Exposure to Resistance of Escherichia coli to Germicide N

culture. However, in light of the effect of dead cells, and the action of sublethal doses of germicides on the general activity of both the germicide and the sensitivity of the cells, it would not be indicated that an increased resistance of any consequence to cationic germicides is to be anticipated.

THE SPECIFIC ACTIVITY OF CERTAIN CATIONIC GERMICIDES AGAINST *AEROBACTER AEROGENES AND ESCHERICHIA COLI* FROM THE STANDPOINT OF TOTAL KILL

Many cationic germicides are becoming available for commercial use with a variety of indicated characteristics. Considerable variation is evident among certain of these compounds insofar as their germicidal activity against *Escherichia coli* and *Aerobacter aerogenes* may be concerned and more particularly as to their reaction in capsule or slime penetration.

Germicide C. From the standpoint of total killing it was indicated that germicide C was more effective against a non-capsulated *Aerobacter aerogenes* than against *Escherichia coli* or a capsulated *Aerobacter aerogenes.* This specific germicide appears to be most active against the non-capsulated types in dilutions of 1:10,000 or more when the exposure can be prolonged for 10 or more minutes. Although indicating some activity toward the encapsulated *Aerobacter aerogenes* (Fig. 1), its slime penetrating properties may need enhancing by some activating agent.

Germicide D. Germicide D acts somewhat differently from germicide C in its action on the three commonly used non-spore-forming types to determine germicidal activity. *Aerobacter aerogenes* and *Escherichia coli* were completely killed (Fig. 2) in approximately the same rate and in relatively the same periods of exposure. In the case of germicide D, however, it should be noted that certain penetrating properties were evident as the capsulated *Aerobacter aerogenes* was completely killed in dilutions comparable to those required to kill the non-capsulated strains. All the cationic germicides have surface tension reducing properties which may be a function of slime penetration. In the case of germicide D this slime penetrating property, although slow on short exposures, becomes increasingly evident at the end of 8 to 9 minutes.

Germicide H. Although more active than germicide C in completely penetrating and killing the capsulated strain of *Aerobacter aerogenes* (Fig. 3), germicide H is less active than germicide D against such slime producing types.

Germicide G. Although particularly effective from the standpoint of total killing in a high concentration, germicide G appeared also to indicate considerable non-specificity (Fig. 4) in regard to killing completely the three test organisms. Cationics of this general type may, due to their apparent non-specific action, have a definite general use in practice, while the cationics with more specific germicidal activities may in turn be applicable for special conditions and operations.

Germicide F. As in case of germicide G, the action of germicide F against the non-spore-forming test organisms (Fig. 5) indicates that it is a non-specific germicide, particularly against certain vegetative cells.

Germicide B. Germicide B (Fig. 6), in contrast to certain other cationics, appears to be somewhat specific in its action against the non-spore-forming types used in this series of studies. It is indicated that although closely related to germicide D, chemically differing only in substituting a cresol for the phenol ring, it failed in comparable penetrating properties insofar as capsules are concerned. Germicide B appeared very active against non-capsulated *Aerobacter aerogenes* and *Escherichia coli.*

Germicide A. The apparent specificity against the test organisms in this series of studies is again indicated (Fig. 7) by germicide A which was exceedingly active

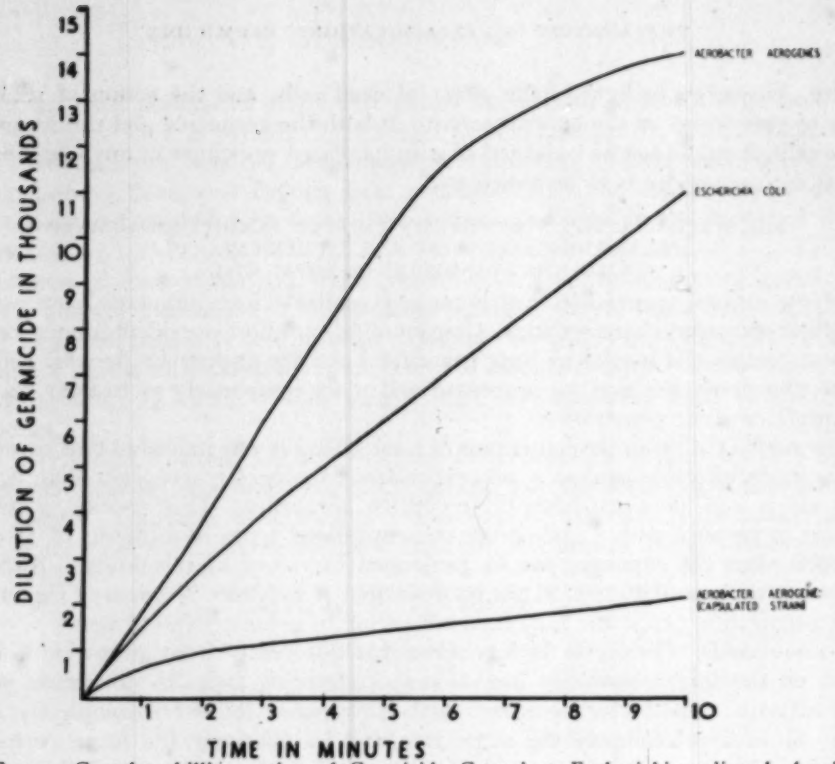


FIG. 1. Complete killing action of Germicide C against *Escherichia coli* and *Aerobacter aerogenes*.

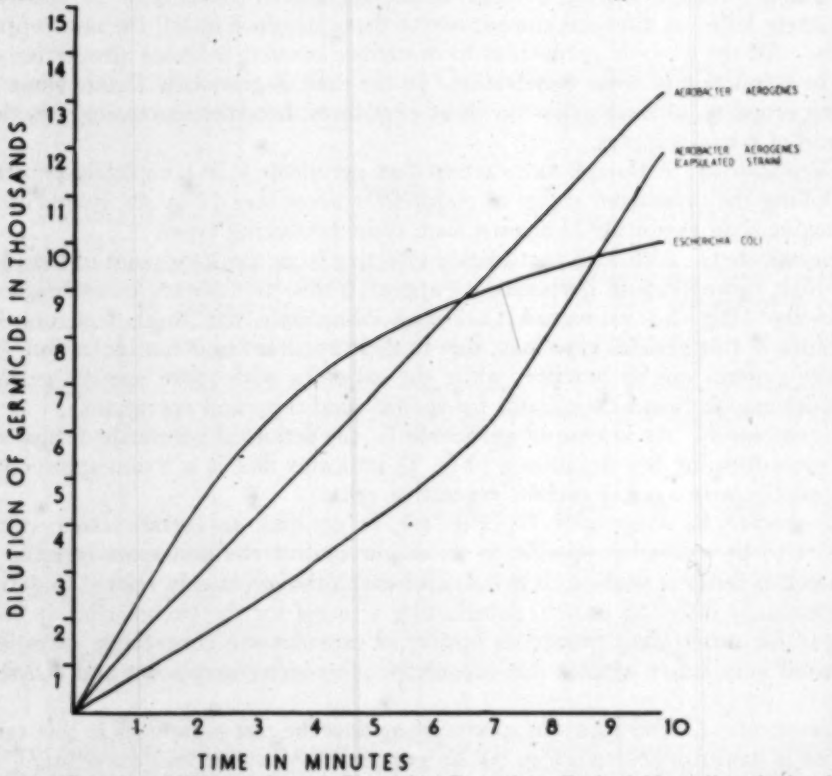


FIG. 2. Complete killing action of Germicide D against *Escherichia coli* and *Aerobacter aerogenes*.

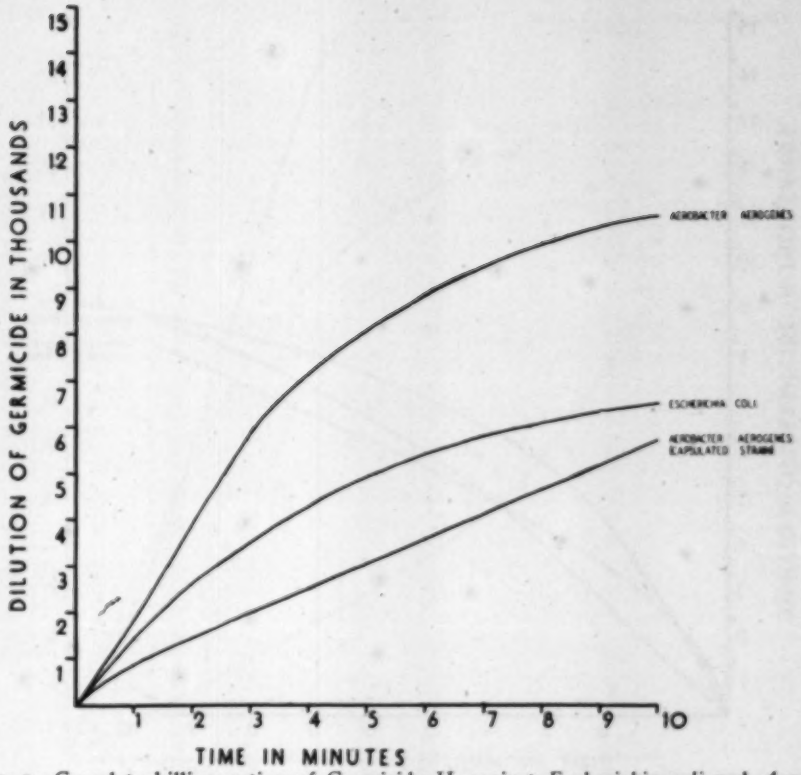


FIG. 3. Complete killing action of Germicide H against *Escherichia coli* and *Aerobacter aerogenes*.

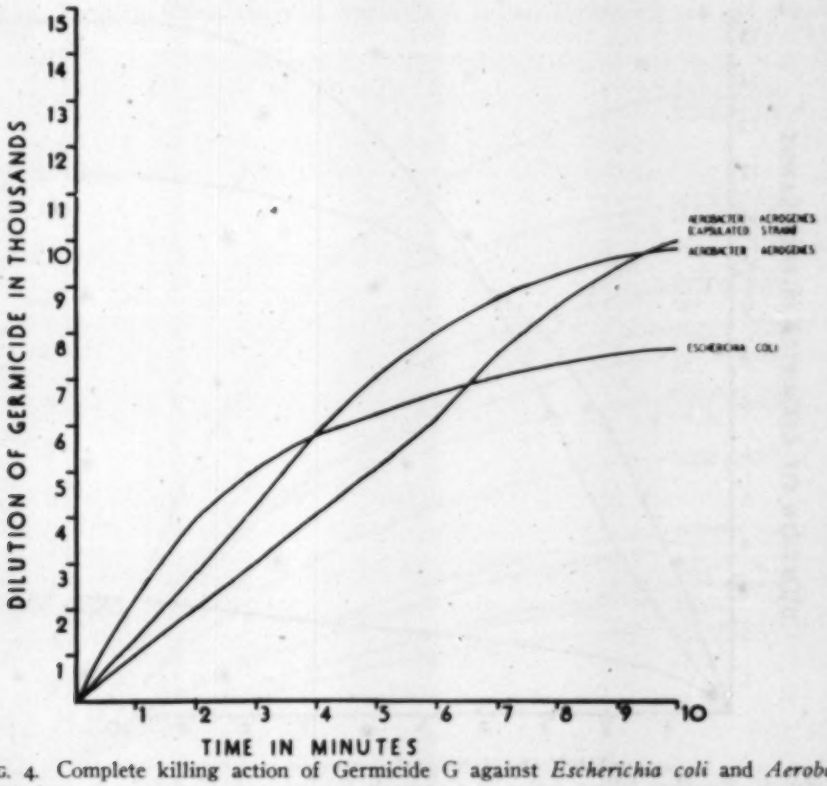


FIG. 4. Complete killing action of Germicide G against *Escherichia coli* and *Aerobacter aerogenes*.

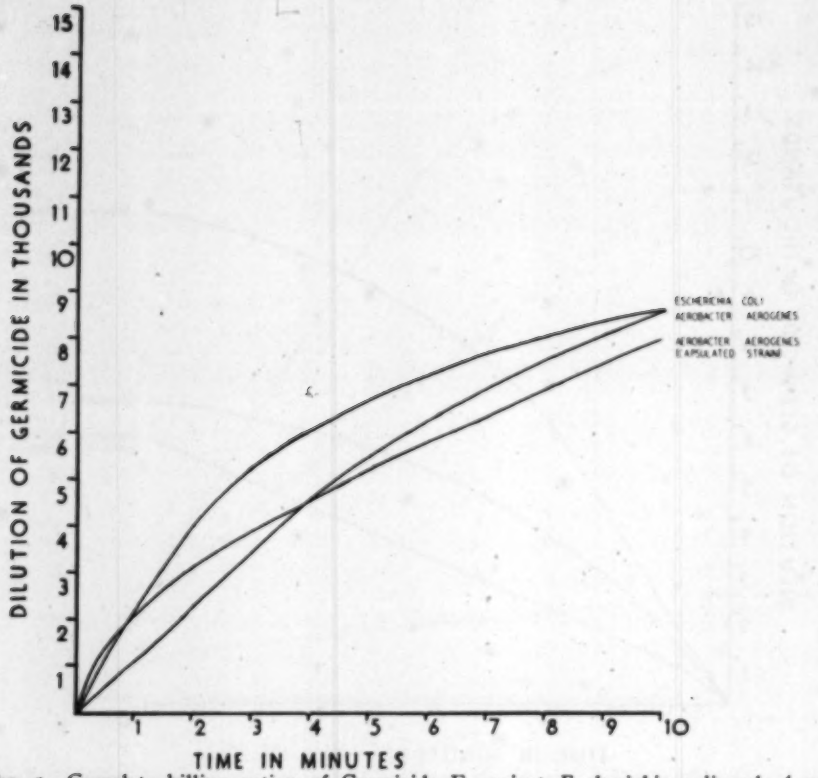


FIG. 5. Complete killing action of Germicide F against *Escherichia coli* and *Aerobacter aerogenes.*

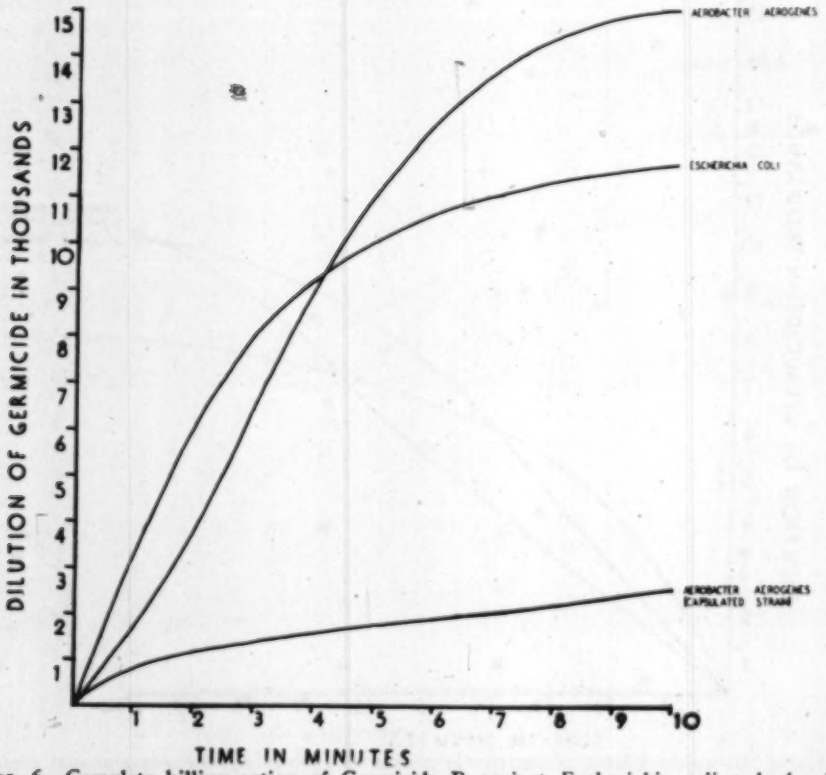


FIG. 6. Complete killing action of Germicide B against *Escherichia coli* and *Aerobacter aerogenes.*

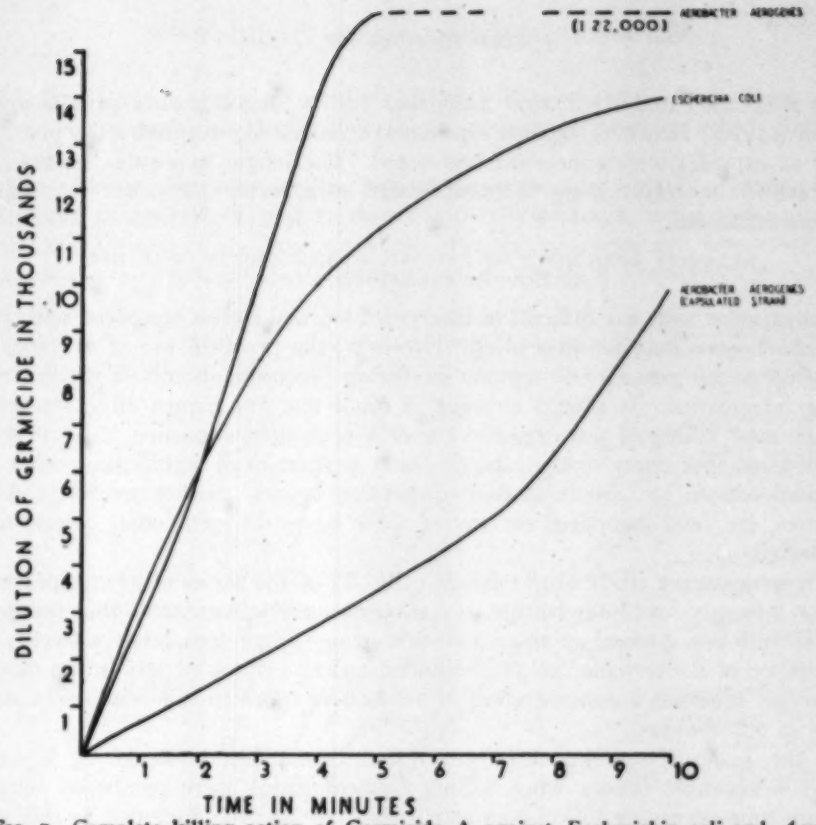


FIG. 7. Complete killing action of Germicide A against *Escherichia coli* and *Aerobacter aerogenes*.

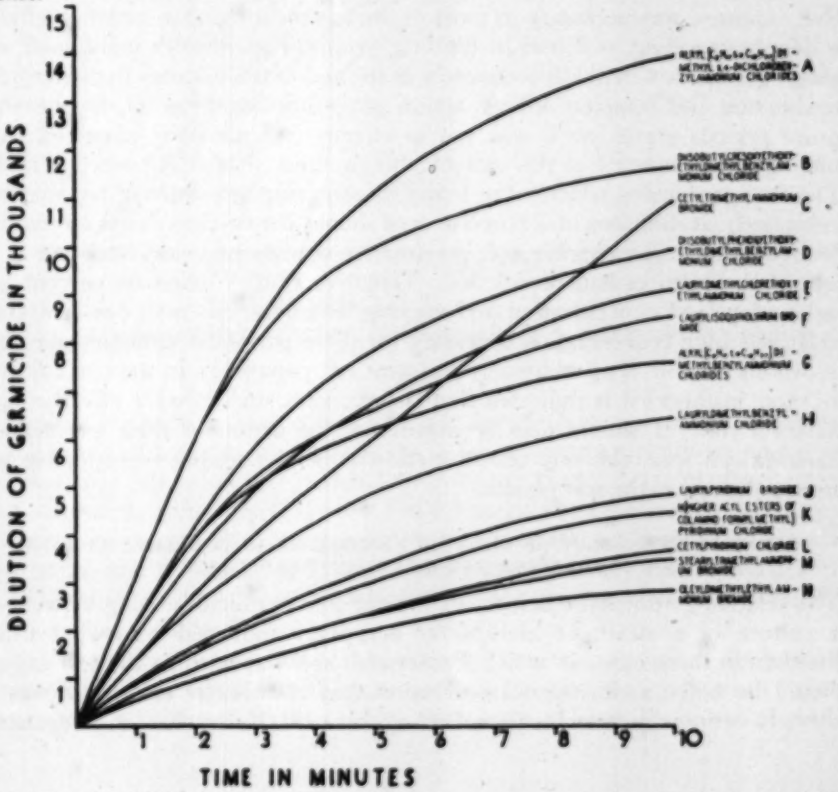


FIG. 8. Complete killing of *Escherichia coli* by a representative series of cationic germicides.

against non-capsulated *Aerobacter aerogenes* and in long exposure periods against *Escherichia coli*. However, against capsulated strains a lag in penetrating properties insofar as capsules were concerned was noted. The longer exposures on the other hand resulted in total killing of encapsulated *Aerobacter aerogenes* in relatively high concentrations.

RELATIVE EFFICIENCY OF CATIONIC GERMICIDES IN COMPLETE KILLING OF *ESCHERICHIA COLI*

Comparative tests are difficult of interpretation and unless tempered with judgment, conclusions may be misleading. However, the practical use of cationics and their selection for general and specific sterilizing processes should be predicated on definite information. It should be kept in mind that the comparative studies are based on total killing of test organisms over a prolonged exposure. Also it should be considered that many of the cationics have properties of significance other than germicidal action, *i.e.*, emulsification, dispersion agents, surface tension reducing properties, etc., and compared on any of these bases different other merits might be indicated.

In a comparative study of the action (Fig. 8) of the series of germicides under study on a twenty-four hour culture of *Escherichia coli* it was found that the germicides fell into two general groups. The first group killed completely a twenty-four hour culture of *Escherichia coli* in concentrations of 1:7,000 or less in ten minutes. The second required a concentration of 1:6,000 or more to kill completely such a culture in ten minutes.

Of this group it was noted (Fig. 8) that germicides A, B, D, E, F, and G showed comparable curves when killing concentrations were compared with the exposure time necessary to kill completely *Escherichia coli*. Included in this group also was germicide C. However, in the case of this particular cationic a longer relative exposure was necessary in most of the lower dilutions in order to effect the same degree of killing as found in the first group of germicides mentioned above. Although germicide C will kill completely at the end of ten minutes in concentrations approximating the complete killing action of germicides B or D, in the shorter exposure periods germicide C was not as effective. Thus there appeared to be a definite lag in the activity of this cationic during these shorter exposure periods.

The five germicides which were found as requiring exposure of ten minutes to kill completely at dilutions of 1:6,000 or less should not be considered as completely ineffective against *Escherichia coli*, as further studies may indicate that a large percent of the cultures had been killed. Tentative studies based on percent killing at various levels of concentration and varying time intervals may demonstrate that the relatively high concentration necessary for these particular cationics may be due to an overall percent of an extremely resistant cell population in the test culture.

In most instances it is indicated that the cationics studied were effective against *Escherichia coli*. It should also be noted that the action of these germicides on *Escherichia coli* was relatively constant and the results readily reproducible with a minimum of skips in the test results.

RELATIVE EFFICIENCY OF CATIONIC GERMICIDES IN COMPLETE KILLING OF *AEROBACTER AEROGENES* (NON-CAPSULATED)

The relative germicidal efficiency of the cationic germicides using a twenty-four hour culture of a strain of *Aerobacter aerogenes* indicated somewhat different results than in those cases in which *Escherichia coli* was used as the test organism. It should be noted as an overall conclusion that *Aerobacter aerogenes* was more sensitive to cationic germicides than *Escherichia coli*. If *Aerobacter aerogenes* is to

be used as a test organism complete killing will be noted in much lower concentrations of the germicide than will be found in those instances in which *Escherichia coli* is used.

The relative effectiveness (Fig. 9) of the germicides against *Aerobacter aerogenes* was, in general, similar to the relative effectiveness of the same germicides against *Ecsherichia coli*. There were certain exceptions, however, when the two test organisms were compared. In those cases in which *Escherichia coli* was used,

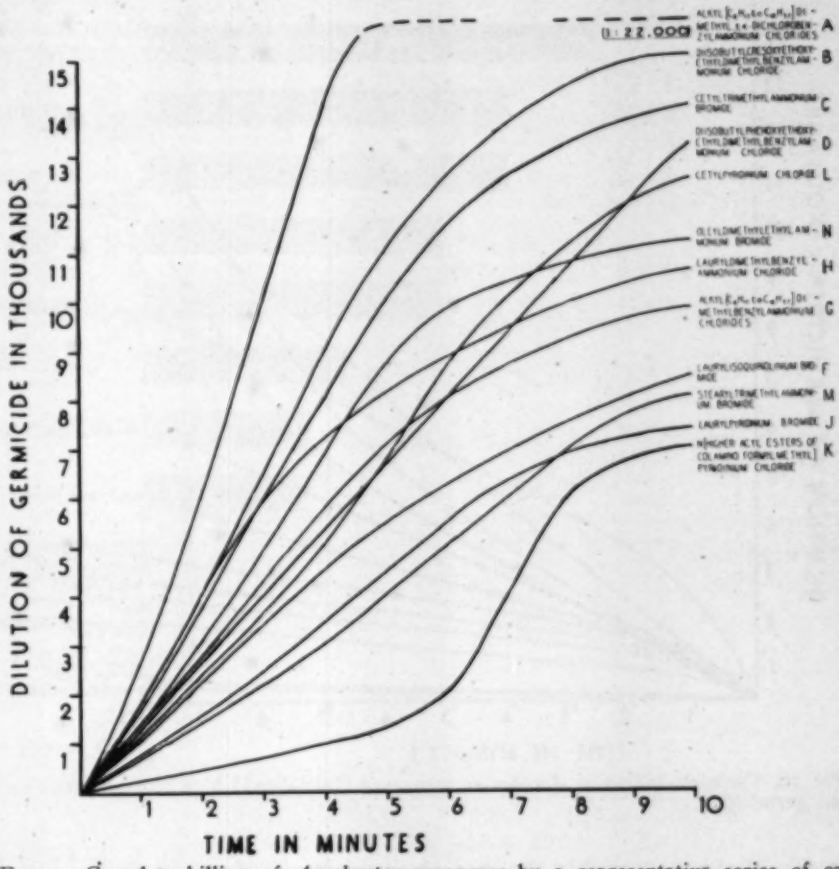


FIG. 9. Complete killing of *Aerobacter aerogenes* by a representative series of cationic germicides.

germicide N could not be considered as an effective germicide, as a 1:3,000 dilution was necessary to kill completely in ten minutes a twenty-four hour culture of *Escherichia coli*. However, when a twenty-four hour culture of *Aerobacter aerogenes* was used, a concentration of only 1:11,000 was necessary to kill completely *Aerobacter aerogenes* after an exposure of ten minutes. A similar observation was noted in the case of germicide L, which was not marked in its effectiveness in completely killing *Escherichia coli* but which killed *Aerobacter aerogenes* in ten minutes at a dilution of 1:12,000.

On the contrary, when *Aerobacter aerogenes* was used *in lieu* of *Escherichia coli*, certain germicides which acted approximately in the same dilutions with both cultures may be given different relative efficiencies. Germicide F completely killed

both *Escherichia coli* and *Aerobacter aerogenes* in approximately the same concentration, *i.e.*, 1 :8,000 after ten minutes exposure; and inasmuch as the more effective cationic germicides completely killed *Aerobacter aerogenes* in more dilute solutions at the end of ten minutes than was found in the case of *Escherichia coli*, it should be concluded on the basis of *Aerobacter aerogenes* that this cationic is not as effective relatively as many of the other cationic germicides being studied.

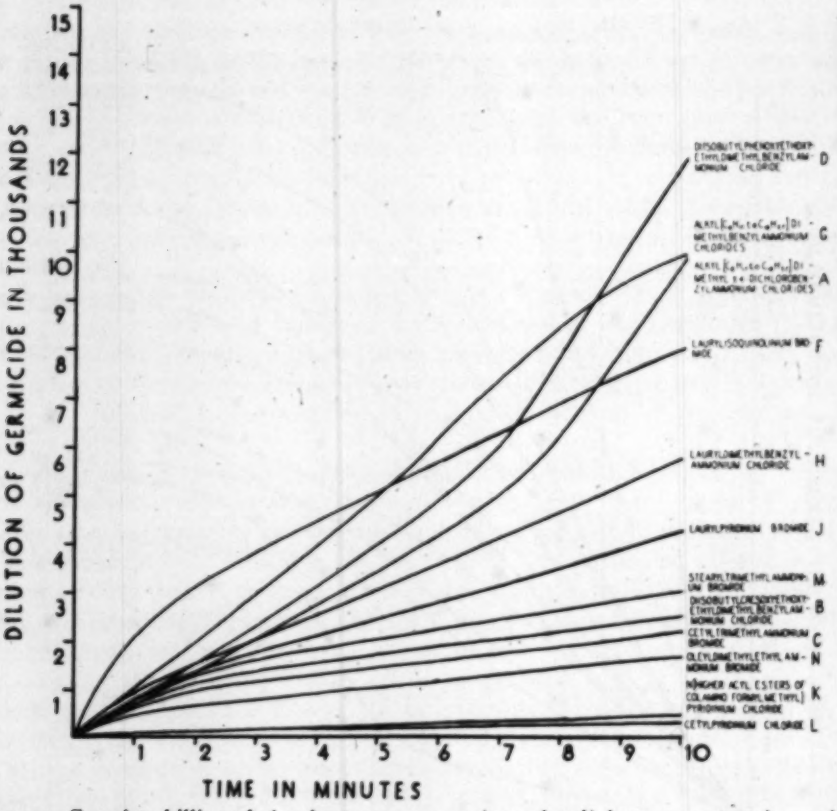


FIG. 10. Complete killing of *Aerobacter aerogenes* (capsulated) by a representative series of cationic germicides.

It should also be noted in the case of germicide C when *Aerobacter aerogenes* was used that the type of curve indicating a definite lag effect in the early stage of exposure was not evident. However, this lag of effectiveness in the shorter periods of exposure was noted in the case of germicide D and several others when *Aerobacter aerogenes* was used as a test culture.

It is indicated in general that *Aerobacter aerogenes* is less resistant to the cationics than *Escherichia coli*. In reporting the effectiveness of these germicides, consideration should be given to the test culture used even though both *Escherichia coli* and *Aerobacter aerogenes* are Gram negative.

RELATIVE EFFICIENCY OF CATIONIC GERMICIDES IN COMPLETE KILLING OF *AEROBACTER AEROGENES* (CAPSULATED STRAIN)

Under operating conditions, particularly in paper pulp mills and in many instances in food and dairy plants, resistant organisms of the *Aerobacter aerogenes*

group are encountered which are encapsulated and produce definite slimy growth on the surface of equipment. These deposits of slime due to capsulated *Aerobacter aerogenes* are difficult to remove and more difficult for the germicide to penetrate. To study the relative effectiveness of cationic germicides on these slime-producing types a twenty-four hour culture of a capsulated strain of *Aerobacter aerogenes* was used. In all tests, the production of slime in the culture was evident and in certain instances the slime was sufficiently pronounced to cause a definite precipitation in the bottom of the culture tubes.

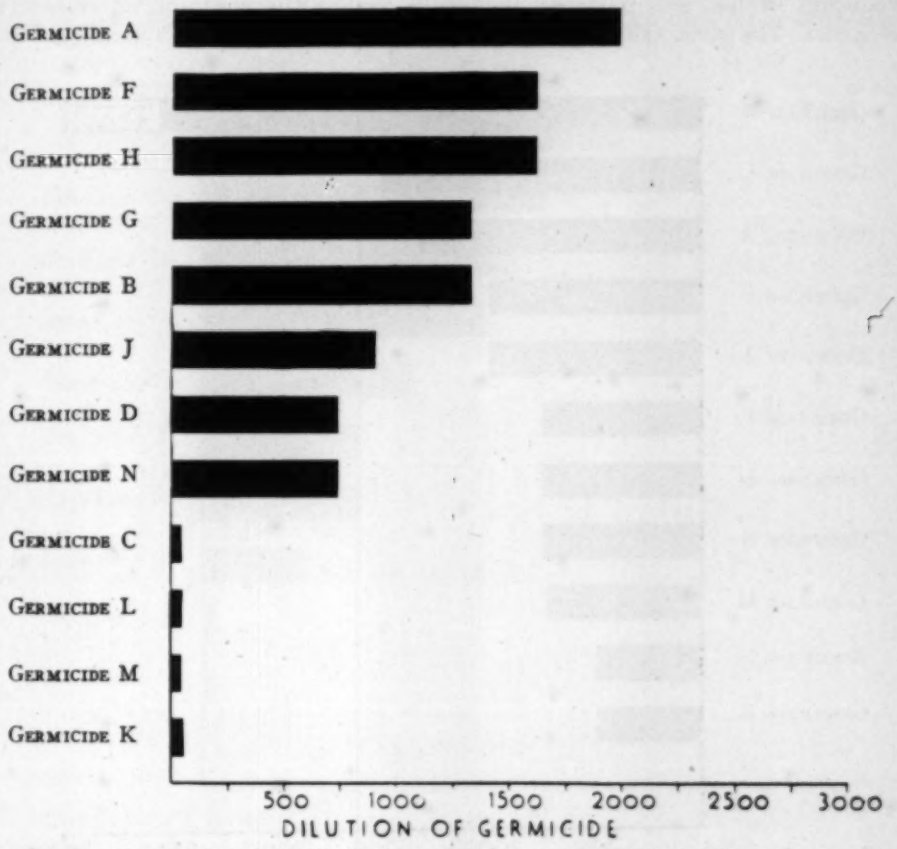


FIG. 11. Complete killing of *Bacillus subtilis* spores in less than ten minutes by a series of cationic germicides.

A study of the results (Fig. 10) indicated that in most instances the capsulated strain of *Aerobacter aerogenes* was much more resistant to the action of the cationic germicides than the noncapsulated strains of *Aerobacter aerogenes* and *Escherichia coli*. In fact, in the shorter periods of exposure it was necessary to use relatively high concentrations of the germicides in order to kill completely the capsulated strain of *Aerobacter aerogenes*. The most effective cationic germicides as determined by their action on the non-capsulated *Escherichia coli* and *Aerobacter aerogenes* were generally the most effective when a capsulated strain was used. However, there are one or two striking exceptions to this general conclusion. It should be noted that when the capsulated strain of *Aerobacter aerogenes* was used as a test organism the cationic germicides again fall into two general groups, those

which completely kill the capsulated *Aerobacter aerogenes* in dilutions of 1:5,000 or more at the end of a ten minute exposure and those which require a 1:4,000 dilution or less to kill completely a similar culture at the end of ten minutes.

In comparing the relative effectiveness of the cationic germicides against the slime producing *Aerobacter aerogenes* as against *Escherichia coli* and the noncapsulated *Aerobacter aerogenes*, certain cationic germicides which were effective on the non-slime strains were relatively ineffective against the slime-producing *Aerobacter aerogenes*. Germicide B, which was relatively effective against the non-slime-producing strains, was relatively ineffective against the encapsulated *Aerobacter aerogenes*. The same was true in the case of germicide C and in part germicide N.

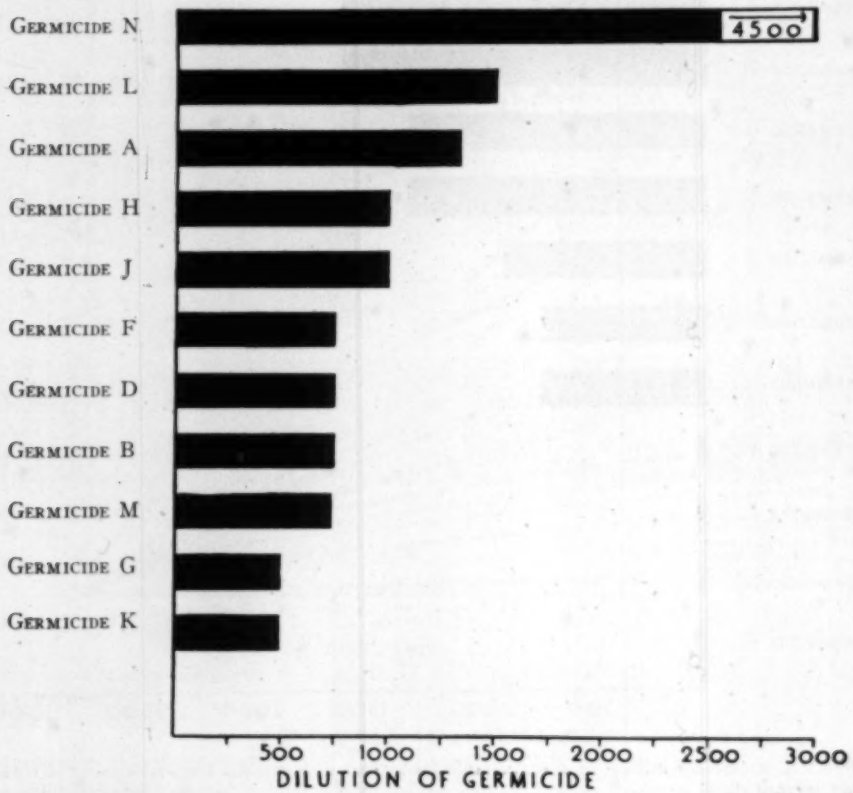


FIG. 12. Complete killing of flat sour type (1518) spores in less than ten minutes by a series of cationic germicides.

In an overall observation of the relative activity of these cationic germicides, particularly on the slimy *Aerobacter aerogenes*, the same relative efficiency did not exist in the higher concentrations and shorter exposure periods as in the lower concentrations and longer exposures. It should be noted that several of the cationic germicides studied appeared to give a curve of activity which had a definite lag in the shorter periods of exposure and to rise quickly as the periods of exposure reached eight to ten minutes. This apparent lag in the action of the germicide may be due in these instances to the slow penetration of the germicide through the capsule of the slimy strain of *Aerobacter aerogenes*.

RELATIVE EFFICIENCY OF CATIONIC GERMICIDES IN COMPLETE KILLING OF *BACILLUS SUBTILIS*

In studying the total killing action of the cationic germicides against spore-bearing types it is obvious that much lower dilutions of the germicides will be necessary than in the case of the non-spore-bearing types. In preliminary studies it became evident that the resistance of spores to the cationic germicides was entirely distinct from the resistance of vegetative cells.

In the case of vegetative cells the relation of the concentration and time of exposure to kill completely followed a definite curve. The relative amount of killing was a matter of degree with a distinct relationship between killing concentration and

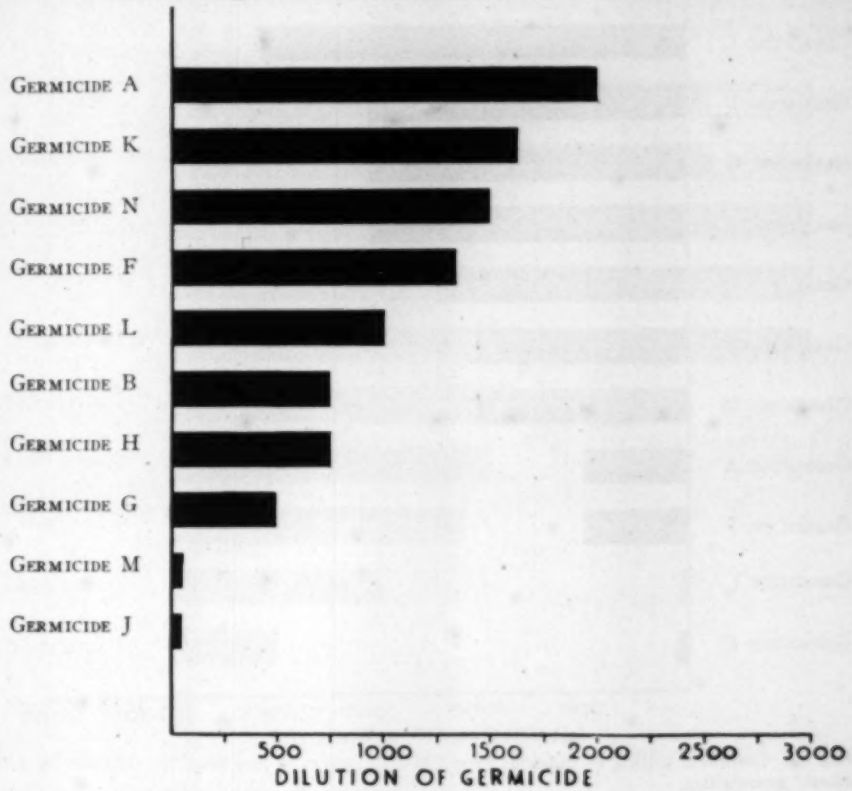


FIG. 13. Complete killing of flat sour type (1503) spores in less than ten minutes by a series of cationic germicides.

time of exposure. When killing of spores was studied it was noted in the preliminary investigations that the degree of killing was not significant but sharp differences were found at particular and specific concentrations. For example, in certain instances, complete killing could not be noted with a definite concentration in ten minutes whereas in an only slightly lower dilution complete killing was apparently effected in less than one minute.

With this preliminary observation as a basis, it was concluded that a preliminary study of the germicidal activity on spores should follow an approach not exactly similar to that used in studies on vegetative cells. As a result, it was concluded to determine in the present study the dilutions at which complete killing of specific spores was effected within an exposure of ten minutes.

In studying the effect of cationic germicides on spore suspensions of *Bacillus subtilis*, it was noted that the germicides again could be divided into two groups, those which completely killed *Bacillus subtilis* spores in dilutions of 1:1,000 or more in ten minutes, and those which failed to kill such spores in dilutions of 1:1,000 in ten minutes' exposure (Fig. 11). Germicide A in a dilution of 1:2,000 completely killed a suspension of *Bacillus subtilis* spores (800,000,000 spores per cc.) on exposure to the germicide for ten minutes. In addition, germicides F, H, G and B killed spores in dilutions of greater than 1:1,000 on exposures of ten minutes.

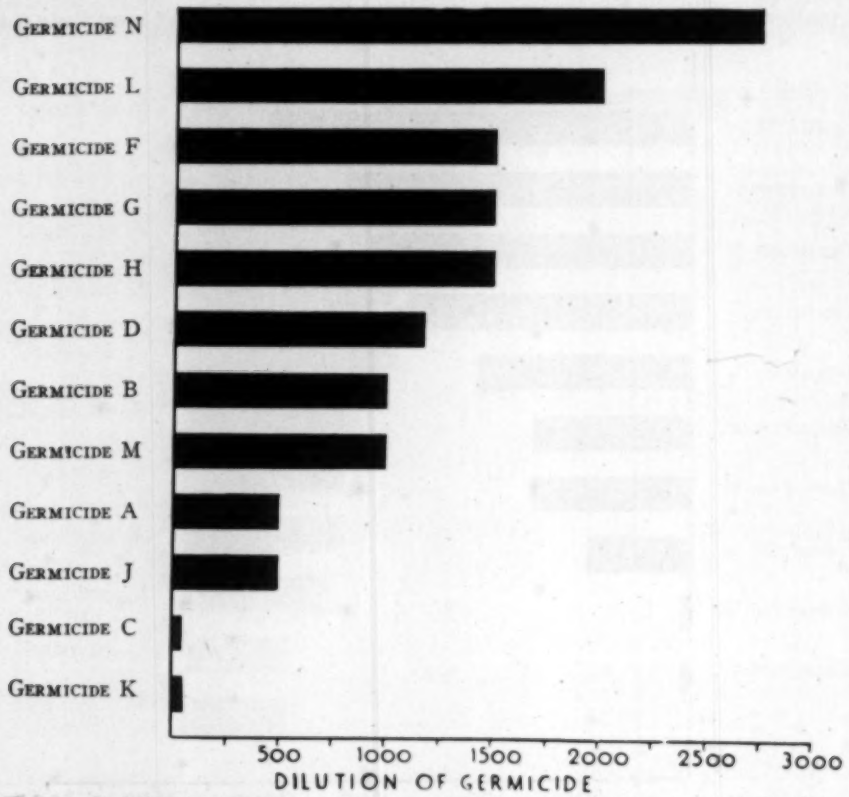


FIG. 14. Complete killing of flat sour type (M-23) spores in less than ten minutes by a series of cationic germicides.

RELATIVE EFFICIENCY OF CATIONIC GERMICIDES IN COMPLETE KILLING OF A FACULTATIVE THERMOPHILIC FLAT SOUR ORGANISM (NO. 1518)

The effect of these germicides on a facultative thermophilic flat sour organism (No. 1518) was comparable in many ways to the results obtained from the study of the complete killing of *Bacillus subtilis* spores. However, in these instances (Fig. 12), it was noted that germicide N completely killed these thermophiles in dilutions as high as 1:4,500 on exposure for ten minutes. This is in distinct contrast to the action of this same cationic on spores of *Bacillus subtilis* in which case a dilution of 1:750 was required during an exposure of ten minutes. In contrast, germicide B which killed *Bacillus subtilis* spores in a dilution of 1:1,350 required a dilution of 1:750 for ten minutes to kill spores of the thermophile No. 1518. It should be noted also that germicide L which was inactive against *Bacillus subtilis* spores killed spores of No. 1518 in dilutions of 1:1,500 when exposed for ten minutes.

RELATIVE EFFICIENCY OF CATIONIC GERMICIDES IN COMPLETE KILLING OF AN OBLIGATE THERMOPHILIC FLAT SOUR ORGANISM (NO. 1503)

The relative efficiency of these germicides against an obligate thermophilic flat sour organism (No. 1503) indicated (Fig. 13) that germicides A and N completely killed these spores in dilutions of 1:1,500 or slightly more when exposed for a period of ten minutes. Germicide L appeared to be active in completely killing culture No. 1503 in sharp contrast to its effect on *Bacillus subtilis* spores.

RELATIVE EFFICIENCY OF CATIONIC GERMICIDES IN COMPLETE KILLING OF A REPRESENTATIVE FLAT SOUR TYPE, CULTURE NO. M-23

In addition to *Bacillus subtilis* and the thermophilic spore-formers, a series of tests was carried out using a typical mesophilic flat sour type of spore-bearing

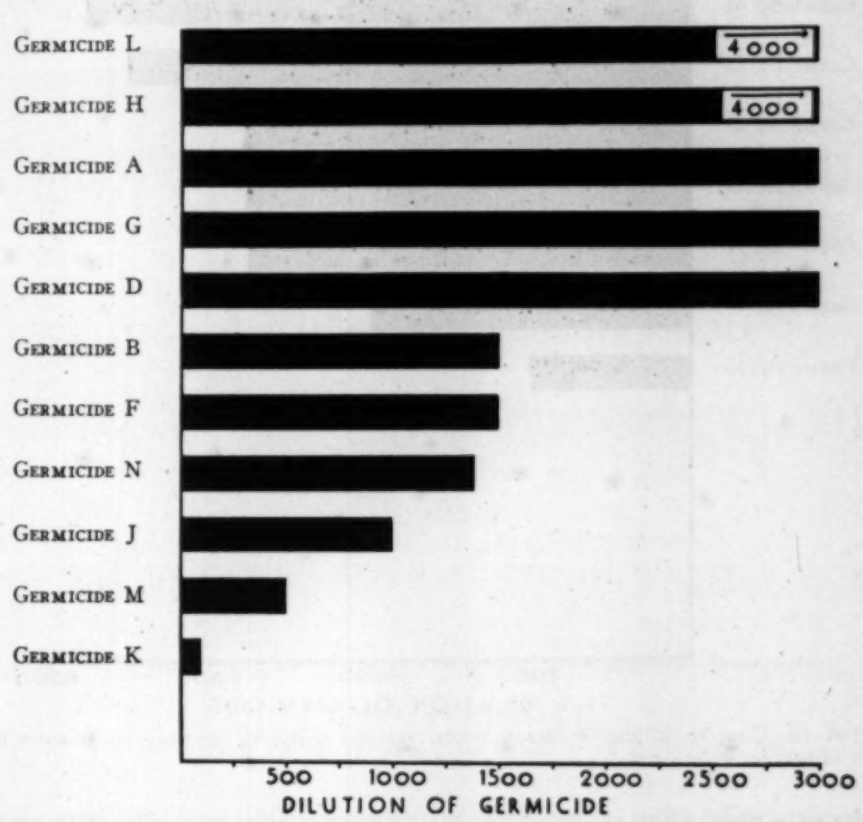


FIG. 15. Complete killing of *Micrococcus aureus* spores in less than ten minutes by a series of cationic germicides.

organism (M-23). In this instance (Fig. 14) the spores appeared more sensitive to the action of the cationic germicides as all but four germicides killed M-23 spores in dilutions of 1:1,000 or more when exposed for a period of ten minutes. One striking observation, however, in connection with the action of cationic germicides on M-23 was the effect of germicide A. In previous instances, this cationic appeared to be among the most effective cationic germicides in bringing about complete killing of vegetative cells and spores. However, in the case of the flat sour type M-23 it appeared to be relatively ineffective.

RELATIVE EFFICIENCY OF CATIONIC GERMICIDES IN COMPLETE KILLING OF *MICROCOCCUS AUREUS*

Preliminary studies indicated that *Micrococcus aureus*, although a non-spore-bearing organism, may react to the cationic germicides similarly to the spore-bearing types. For this reason, when *Micrococcus aureus* was used as the test organism to determine the relative efficiency of cationic germicides, it appeared from such information as is now available that the results cannot be expressed linearly but must be presented in a dilution necessary for complete killing during exposure for a given length of time.

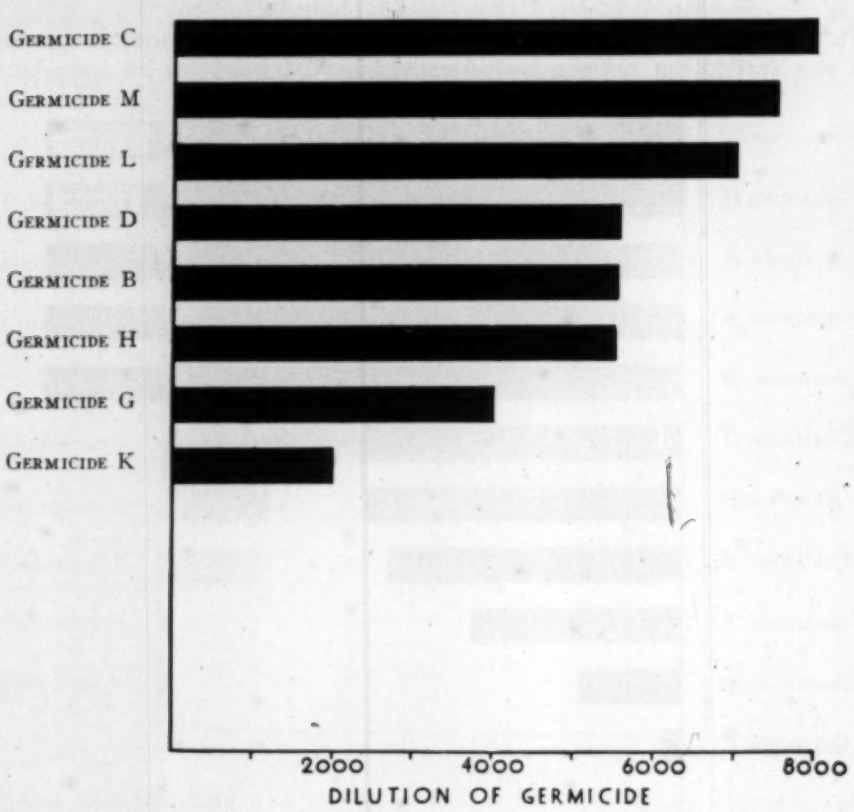


FIG. 16. Complete killing of *Streptococcus cremoris* spores in less than ten minutes by a series of cationic germicides.

It can be noted (Fig. 15) again that the compounds effective against *Micrococcus aureus* fall into two groups, one which completely killed a twenty-four hour culture of *Micrococcus aureus* in dilutions greater than 1:1,500 when exposed for ten minutes, and those which require a dilution of 1:1,500 or less. Germicides L and H were found to kill completely *Micrococcus aureus* in a dilution as high as 1:4,000 when exposed for ten minutes. This observation is of interest when it is noted that germicide L did not indicate the same relative efficiency on the other test cells, although it was effective on spore-bearing types 1518 and M-23. Again it was noted that germicide H was not particularly effective against certain vegetative cells, although it was relatively effective against *Bacillus subtilis spores*. Germicides G, A and D were found to be relatively effective against *Micrococcus aureus*.

RELATIVE EFFICIENCY OF CATIONIC GERMICIDES IN COMPLETE KILLING OF *STREPTOCOCCUS CREMORIS*

Streptococcus cremoris was selected for study inasmuch as it serves as a basis for most dairy starters. In addition, there is meager evidence to indicate that the bacteriophage which is a contamination of many dairy starters, particularly in cheese, may be sensitive to cationic germicides.

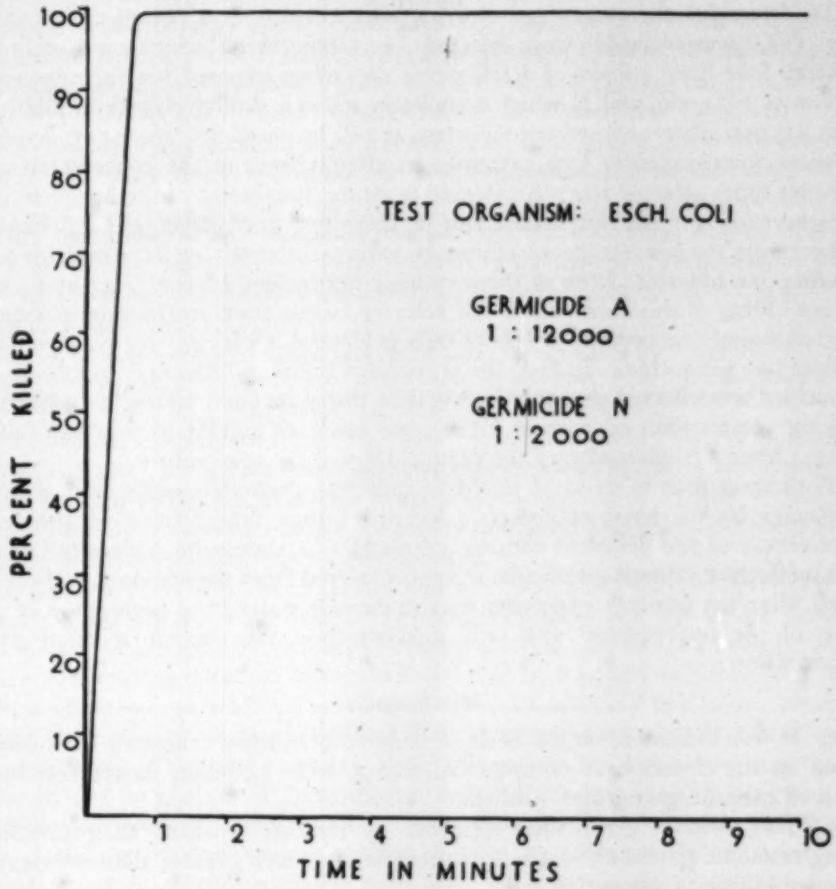


FIG. 17. Percent killing by Germicides A and N of *Escherichia coli*.

Streptococcus cremoris was relatively sensitive to the action of cationic germicides. However, the nature of its resistance to cationic germicides (Fig. 16) was similar to that of *Micrococcus aureus* and the spore-bearing types rather than showing a similarity to the vegetative cells. Again, there was indication that cationic germicides may show some specificity against certain types of organisms. Germicide C, together with germicide M and L, were the most effective against *Streptococcus cremoris*. These cationic germicides completely killed *Streptococcus cremoris* in dilutions of 1 :6,000 or more when exposed for ten minutes. Germicides D, B, H, and G all showed an effective range of dilutions of 1 :4,000 to 1 :6,000 when exposed for ten minutes to kill completely *Streptococcus cremoris*, while germicide K required a concentration of 1 :2,000.

RATE OF GERMICIDAL ACTION

It is realized that the above results have been based upon a complete killing of the test organism. It is also obvious, from results that have been presented by many workers in the field of germicides, that a large percentage of the organisms in any given culture are sensitive to germicides with a few remaining cells showing increased resistance. These few cells mask the effectiveness of the germicide when a complete killing becomes the basis for testing the efficiency of the germicide.

To determine the percentage of organisms killed over a period of ten minutes (Fig. 17), two germicides were selected, *i.e.,* Germicide A which completely killed a twenty-four hour culture of *Escherichia coli* when exposed for ten minutes in a dilution of 1:14,000, and N which completely killed a similar culture in dilutions of about 1:3,000 when exposed ten minutes. It will be noted that these two germicides represent approximately two extremes in effectiveness at the concentrations and exposure times selected when considered from the standpoint of the complete killing of *Escherichia coli.* Studies were made on these two germicides on *Escherichia coli* to determine the percentage of killing at various intervals of exposure up to and including ten minutes. Both of these cationic germicides effected a greater than 99 percent killing of the *Escherichia coli* cultures in less than one minute of exposure. The remaining one percent or less of cells evidenced a varying degree of resistance to these two germicides. In fact, the 99 percent killing which was found with these germicides was effected probably in less than thirty seconds, as the first observation showing greater than 99 percent killing was made as quickly as possible (about 1 minute) after a combination of the germicides and the test culture.

With these data in mind, it would be indicated that while evaluation of cationic germicides on the basis of *complete* killings brings into bold relief the relative effectiveness of the different cationic germicides, it should be understood that the most ineffective cationic germicide, when considered from the standpoint of complete killing after ten minutes exposure, may materially reduce the percentage of population of the test culture with only a short time exposure in a relatively low concentration.

CONCLUSIONS

1. It was indicated, on the basis of relative germicidal efficiency with complete killing as the criterion of comparison, that a wide variation exists between the series of cationic germicides studied.
2. The cationic germicides appeared to indicate promise as germicides in killing resistant spores although in concentrations much greater than necessary for complete killing of vegetative cells.
3. A high degree of specificity was indicated as between different cationic germicides, particularly as far as flat sour spores are concerned.
4. There was little or no reaction as between metals used in fabricating processing equipment and effectiveness of cationic germicides. None of the cationics studied indicated any corrosive action.
5. It was indicated that even the most ineffective cationic germicide from the standpoint of total killing may kill a large percent of the cell population even on short exposure.

OBJECTIVE MEASUREMENTS OF QUALITY IN FOODS[1]

HOWARD R. SMITH
National Canners Association, Washington Research Laboratory

By an objective measurement we mean one which is based on observations from which the attitude of the investigator is entirely excluded. Perhaps it can be further described by contrast with a subjective test. Subjective tests are based on physiological reactions which are the result of the training and experience of the individual and are influenced by his personal preferences, powers of perception, etc. They do not lend themselves to accurate measurements or numerical evaluations. Food technologists find them unsatisfactory and of limited application. Objective measurements, on the other hand, are based on recognized standard scientific tests which can be applied by any competent investigator with a satisfactory degree of accuracy. They are applicable to any sample of the product without regard to its previous history or ultimate use. They are the kind of tests that are demanded in every official standard of quality under the Food, Drug, and Cosmetic Act. Lord Kelvin summarized these tests as follows:

> "If you can measure that of which you speak, and can express it by a number, you know something of your subject; but if you cannot measure it, your knowledge is meagre and unsatisfactory."

In developing objective tests for the determination of quality factors in foods, it is desirable, in fact, almost necessary to subdivide each quality factor into particular properties which will lend themselves to accurate measurement. To the extent that each study can be limited to a single accurately described characteristic, there is the possibility for a satisfactory test to be developed.

For each such carefully circumscribed characteristic, there may be developed one or more satisfactory objective tests. The most important one will be the basic or standard test. This should be expressed in basic scientific terms. It should be highly accurate. It will not be used very often since it is designed to serve as a final authority or referee method. Other simpler objective tests for this same characteristic will be developed for the use of industry at various stages in the manufacture or merchandising of the food product. These will vary in sensitivity and in accuracy. The use of one or another of these shorter tests will be indicated by the nature of work being carried on. The food technologist should know the degree of accuracy that is significant for the purpose at hand and be able to select the test which will give that accuracy without involving more time and expense than is necessary.

The foods which the technologist is called on to measure are products of nature. This means that for each individual characteristic there are, among a number of samples, all gradations from the lowest to the highest in the scale of values. It can be said with considerable truth that no two samples are exactly alike in any characteristic. The objective measurement should be accurate and reliable in spite of the varying conditions which may have produced the sample. The interpretation of the results of the measurement may take into account concomitant circumstances but the objective test must be entirely arbitrary.

Some objective tests are so simple as to be almost self-defining. Particular products may well require special tests which are not applicable to foods in general. We cannot hope to cover all of these in one paper, but those tests which are of a general application to foods are discussed briefly below.

---

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 18, 1946.

SIZE OF UNITS

It is possible to measure the physical dimensions of any solid food to any desired degree of accuracy. From large units, such as squashes or watermelons, through medium sized and small products, to fine powders such as flour and to microscopic particles or even to colloidal suspensions, there are instruments available for satisfactory measurements. The basic data might require exact three-dimensional notations or even contour diagrams of each unit, but this is seldom necessary. The size may also be indicated by the weight or volume of each unit.

Where the units are of fairly uniform size, the maximum, minimum, and average values may be sufficient. Where the variation in size is greater, it is helpful to show the proportion of the units that are within certain size limits. This is conveniently done by using appropriate screens, or sieves. United States Standard sieve sizes are available for basic reference. For finer particles the classification may be made by sedimentation with or without the aid of a centrifuge, by air flotation, or by other special methods.

For units of irregular shape, some conventional size designation may be desirable. For example, certain varieties of peas are not round but have three distinct dimensions. The average volume may be determined by displacement and from this value a hypothetic average, assuming that the units are perfect spheres, may be calculated and used to indicate the average size.

Still other methods of indicating size may be used to advantage. The number of units per pound is used for olives. The number of pear halves in the can is stated on the label for the information of the housewife in planning the servings. If the manner of stating the size is clearly understood, there is no reason for avoiding any convenient method of expression.

VISCOSITY, THICKNESS, TEXTURE, CONSISTENCY

These terms have been applied to food products rather indefinitely and somewhat interchangeably. In this discussion they are used in a restricted sense as indicated by the definitions.

Viscosity is the resistance to liquid shear of a liquid or semi-fluid product. The basic unit of viscosity is the "poise," or its more commonly used fraction, the "centipoise." It is measured with a viscosimeter. There are several types of instruments available, some of which are used only with liquids and others which are adaptable to various types of semi-fluid products. The viscosity varies with the temperature so all such data should include a notation of the temperature at which the measurement was made.

Thickness is the resistance to change of shape of a relatively homogeneous, stiff food product, such as custard or prepared pumpkin. There is no basic unit for expressing thickness. Relative values are usually based on the depth of penetration of a plummet. The Universal Penetrometer is a standardized instrument recommended by the American Society for Testing Materials. It is adaptable for use on a wide variety of products. Simpler plummets may be devised for particular products. For example, a six-inch steel machinist's rule may be used for measuring the thickness of canned pumpkin. When allowed to fall vertically into the mass, the depth of penetration may be read on the scale.

Texture refers to the rigidity of solid units of food. There is no basic unit for expressing texture. An instrument has been developed for measuring the hardness or resistance to grinding of grains, powders, and other dry materials. The resistance to crushing of cooked foods may be measured by the instrument used in the Standard

of Quality for canned peas. This same instrument may be used to indicate the firmness of fruits, etc., by measuring the force required to puncture the product. Other puncture testers are also available.

An instrument called the tenderometer has been perfected for measuring the resistance to shearing of certain foods. It was designed especially for testing raw peas, but it is also suited to the testing of raw lima beans, and may possibly be adapted to other foods.

Hard particles, such as the grit (stone) cells in pears may be separated by levigation after the sample has been disintegrated with a Waring Blendor or similar device.

Tough fibers and strings may be separated from the other tissues by treatment with hot alkali or with a Waring Blendor, filtered on a 30-mesh wire screen, dried, and weighed.

Consistency is a general term applied to a mixture of fluid and solid foods. There is no basic unit of consistency. It is a combination of the size and texture of the solid units, the viscosity of the fluid, and the proportion of solids to fluid. Tomato catsup and cream style corn are examples of such products. The general character of such mixtures may be indicated by the rate of flow under empirically established conditions. This may be the rate of flow in a horizontal trough or vertically through a funnel or down an inclined plane. One method uses the area of flow from a central point in a given time. For somewhat thicker products the height of the mass after standing undisturbed for a specified time will show the general consistency.

TURBIDITY

The amount of insoluble material in suspension causing the various degrees of opaqueness of the liquid may be measured by certain colorimeters or by special instruments known as turbidimeters. These are frequently based on the amount of sample necessary for the extinction of a standard light such as a candle flame or a particular electric light. The depth of liquid sample that is necessary for this light to just be invisible is an indication of the turbidity. There are no standard units for expressing turbidity. The nearest approach to a standard for turbidity is that given in the methods of analysis for water which suggest a standard turbid solution containing one part per million of Fuller's Earth which has passed through a 200-mesh sieve.

The amount of undissolved material in the liquid may sometimes be expressed as the volume of undissolved material separated by centrifuging the sample under given conditions. However, since the state of sub-division of the undissolved particles influences markedly the character of the turbidity, it is hardly practicable to indicate turbidity by noting the weight of the undissolved material per unit volume.

COLOR

Basic color evaluations are made with the spectrophotometer. For clear solutions the measurements are of transmittance at particular wave lengths. For opaque products the measurements may be made by reflected light or occasionally the color may be extracted and the valuations made as for clear solutions. The spectrophotometer must be precise enough to use a very narrow band so as to give practically monochromatic light.

For each product the first step is to make color curves with the spectrophotometer showing the transmittance at each wave length. This should be done for several samples varying widely in the color under consideration. Inspection of the curves

will indicate the particular wave length where differences are most characteristic. A method is then set up whereby sufficient sample is used to give satisfactory readings on the spectrophotometer at the particular wave length. The percent transmittance is then an indication of the amount of that color. It may be necessary to determine the transmittance at two or more wave lengths and combine the readings for most satisfactory differentiations.

For many purposes satisfactory color evaluations may be made with less complicated apparatus. One method that is widely used is known as the Munsell color system. This is used officially by the U. S. Department of Agriculture in designating the color requirements of many fruit and vegetable products. It is also endorsed by the National Bureau of Standards and by many scientific societies. In this system the color of the sample is matched directly by a combination of color cards of known color values. The cards are blended by whirling and they can be adjusted to give any combination of the colors used. Particular color cards must be selected for each product. Great care must be used to have the illumination of the cards and samples uniform.

Close approximations to reference color standards may be made by comparing the color of the sample directly with standard color cards, such as those of Ridgeway or Maerz and Paul.

The color of clear solutions may be compared with that of tinted glasses, as in the Lovibond tintometer system, or with the color of certain chemical solutions of standard compositions. Colorimeters of various makes are available for comparing the colors of solutions.

UNIFORMITY OF COLOR

Color differences that are noticeable to the eye may be measured by separating the units visually and measuring the color of each portion separately.

MATURITY OF VEGETABLES

The maturity of cooked peas, corn and lima beans is measured by the proportion of insoluble plant constituents that accompany seed production. This is principally starch. The measurement of starch alone is long and rather involved, so the alcohol insoluble solids content is used as a convenient means for showing the maturity of these vegetables. A great deal of preliminary investigation is necessary in order to establish the normal content of starch and other insoluble constituents of the different varieties, but experiments have shown that the alcohol insoluble solids content is a valid measure of the maturity in peas, corn, and lima beans. In the case of green and wax beans the size of the seed in the pod increases as the maturity advances and so the proportion of seed to pod may be used as an index of the maturity. Also, tough fibers develop which may also be measured. Tough fibers develop in asparagus, beets, carrots, parsnips, and other vegetables, and may be used as an index of maturity.

Certain vegetables increase in specific gravity as they advance in maturity. This is used to indicate the maturity of raw vegetables and of the canned products. Brine solutions of known specific gravity are prepared and the proportion of units that sink or float in such solutions shows the relative maturity.

RIPENESS OF FRUITS

In most fruits as they change from green, immature units to the fully ripe stage of development, there is an increase in the sugar content, a decrease in the acidity, a softening of the tissues, and the green color disappears in favor of the normal color

of ripeness. Each of these changes has been used to indicate degree of ripeness. With citrus fruits the sugar-acid ratio is widely used to express ripeness. With pears, apples, and other fruits, a puncture test is sometimes used. Recently the disappearance of the green color has been shown to be a good index of the ripeness of canned apricots and peaches. In this test, all of the color of the sample is extracted and concentrated as a clear solution. The amount of green color is measured with a spectrophotometer as the percent transmittance at 665 millimicrons. The variations in the intensity and the hue of the characteristic colors of different varieties of peaches and of apricots do not interfere with the measurement of the green color, and the amount of green color present has been found to show the ripeness of all of the varieties tested.

SUCCULENCE

The eating quality of some foods is in relation to the free liquid that is associated with the solid units of the food. Beefsteak should be not only tender but also juicy. Young and tender vegetables are juicy rather than chewy—in fact, they are called "succulent," meaning "juicy" vegetables. It has been found that the volume of juice that can be squeezed out of a sample is an indication of its succulence and to that extent of its acceptability. A simple instrument called a "succulometer" has been devised with which a sample can be pressed to a uniform degree and the volume of juice measured in a graduate. For sweet corn, both raw and canned, this volume of juice is a good index of the canning quality with respect to the maturity of the corn.

FLAVOR

This is by definition a physiological sensation—consisting of taste, or odor, or —in most instances—a combination of taste and odor. The fact that it is inherently subjective means that there cannot be an objective measurement of flavor. However, flavor is an important part of the appreciation of foods and it is quite fitting that food chemists and technologists should continue their investigations to find out more about flavor. The ground work for any study of flavor is still the classic book by Savarin, entitled "The Physiology of Taste." In this most interesting treatise, written in 1825, the four sensations of taste, namely: sweetness, acidity, saltiness, and bitterness, and the multiplicity of odors, and the flavor sensations of various combinations of these factors, are charmingly portrayed. More recent articles and books, notably that by Crocker, have contributed greatly to our understanding of flavor.

The fact that we cannot measure the physiological sensations that make up flavor does not prevent the food technologist from using flavor as a most sensitive indicator in the manufacture of food products. A trained observer working with a few foods for several years can become very expert in distinguishing small variations in flavor which tell him of the success or failure of the factory operations.

INTERPRETATION OF OBJECTIVE MEASUREMENTS

The objective measurement of quality factors is only the first part of the problem confronting the food technologist. He is usually expected to interpret the findings in terms which can be used in the merchandising of the food. This is a less tangible and correspondingly more difficult undertaking. The actual measurements of each lot of food are hardly suited to invoices and label designations. The usual expedient is to establish two or more classifications which range by successive steps from the lowest to the highest value. Definite limits are set for each group and the objective measurement of each lot shows in which group that lot belongs. The dividing line

between groups must be infinitely sharp. There can be no zone of division. Each lot must fall on one side or the other of the dividing line.

How shall the limits for such groups be established? This introduces not a physiological sensation, but a psychological evaluation. Since the food products are intended for human consumption, some consumers feel that they should set the limits. Those who make consumer surveys find that quite often the answers are different from the ones that were expected. Every manufacturing operation has definite limitations so manufacturers are sure they must have a part in any such discussions if the limits are to be practical. Usually it is desirable to set tentative limits which will be reviewed by all concerned for some time and modified when necessary. The fact that the limits are based on standard objective measurements serves to stabilize the thinking of those who are dealing with the problem. There is possible a common understanding of the significance of the limits that may be suggested.

Without objective measurements the food technologist can hardly make a beginning at accurate descriptions or stable evaluations. There can be no accumulation of data on which to build scientific knowledge. If his opinions are challenged, the ensuing argument frequently includes personalities rather than facts.

With objective measurements available as a basis for exact description and common understanding, the work of the food technologist becomes a part of the broad science of food production. He works with others in his field for the perfection of existing measurements and for the development of new instruments with which to measure additional quality factors. His best energies are challenged in the selection of the best method for the desired degree of accuracy, the supervision of experimental packs to study the variations in his product, and the interpretation of the data. Objective measurements do not mean routine examinations. They are the key to real progress in quality control and improvement.

A NEW DEVELOPMENT IN SOLID JUICE CONCENTRATES: A CONSUMER PRODUCT [1]

LAURENCE P. GEER
Vice-President, Prime Products, Inc., Tampa, Florida

A method is described for concentrating citrus and other juices after enzymic degradation of pectin and adjustment of free acid. Such products are described by the trade marked name, "Brucentrates."

An additional step is described in which such concentrates are dehydrated completely to form confections suitable for direct consumption, comparable in food value to the initial juice. These confections are described by the trade marked name, "Bruceets."

Bruceet is a new food, designed not to be reconstituted and consumed as a beverage, but to be consumed as is, directly. New trade channels are opened and outlets provided for agricultural surpluses. It definitely is not a candy and is not expected to compete with candy, but it is essentially and actually a fruit juice in solid form.

The process of producing solid juice concentrates naturally divides itself into two stages. The first stage is concerned with obtaining the juice and concentrating to 80 percent solids. The product at this stage is known under the trade marked name, BRUCENTRATE.

The juice is obtained in whatever manner is common in the industry. In the case of citrus, reaming, pressing, or crushing are usual methods. The juice is immediately pasteurized to destroy whatever enzymes may be present, and, of course, to kill or inactivate microorganisms.

Next it is necessary to remove, or at least degrade, the pectin which is a normal constituent of fruit juices. This is done to avoid jelling of the juice at high concentrations and to facilitate evaporation of the material to dryness without caramelizing or burning of sugars.

For degrading the pectin it is preferable to use a pectin degrading enzyme, but there are other practical methods by which this may be accomplished. In selecting the commercial enzyme preparation best suited for this operation it is necessary to choose one which contains no unwanted enzymes. Most commercial preparations contain more than one enzyme and of course those which will cause oxidation of ascorbic acid or other harmful reactions should not be used. We have found that the best all round pectinase preparation is Pectinol 10M. This enzyme acts at an optimum pH of around 3.5 and at an optimum temperature of about 120° F., though these conditions are not extremely critical. Since the degradation of the pectin is not followed by clarification of the juice, it is possible for the enzyme reaction to take place during the evaporating process. This means that the temperature in the evaporating pan must not be allowed to go above 120° F. This temperature corresponds to a vacuum of not less than 26.5 inches, at which point water boils at 120.6° F. Although the temperature at which juice boils is slightly higher than the optimum temperature at this vacuum, no injury to the enzymes has been observed under these conditions. Higher vacuum than 26.5 inches is advantageous because at higher vacuums the boiling point of the juice is lower and consequently there is less destruction of the sugars by heat. Using a two stage steam jet or a good water

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

jet with adequate water pressure it is possible to obtain easily a vacuum of 28.5 inches with a properly designed vapor line and condenser.

At a vacuum of 28.5 inches the boiling point of water is 91.7° F., although as concentration progresses the boiling point of the material rises due to the higher concentration of the solution being boiled. It is possible to estimate rather closely the concentration of the material in the vacuum pan by referring the boiling point of the material to the boiling point of water under the same conditions of vacuum. The boiling point of the material is determined either by a mercury thermometer or a thermo-couple inserted through the wall of the pan directly into the boiling material. The operator of the vacuum pan is provided with a table showing the boiling points of water at various degrees of vacuum, and by comparing this table with the temperature of the material in the pan the concentration can be determined closely enough for practical purposes.

As previously mentioned, it is necessary to adjust the acidity so that the finished Bruceet will be correct from a taste standpoint. This is done by first titrating the juice before concentrating. Then by simple arithmetic the weight of acid present per gallon of the juice is determined. Next, by reference to tables the weight of dissolved solids per gallon of juice is found. This weight, of course, will vary as the Brix of the original juice varies, and the weight of dissolved solids per gallon shows the weight of finished Bruceet obtainable per gallon of original juice. Since, in the case of citrus Bruceet, for example, the optimum acidity is taken as 3 percent, then the weight of acid desired per gallon of juice is figured as 3 percent of the dissolved solids. This figure is subtracted from the weight of acid present in the original juice and the result is the weight of acid to be neutralized per gallon of original juice. If NaOH is used as the neutralizing agent, then the weight of citric acid to be neutralized multiplied by the combining weight of NaOH gives the weight of NaOH to be added per gallon of original juice. The NaOH can be added to the single strength juice before it enters the evaporator, or it can be added during the concentrating process, whichever is the most convenient. The addition should be made, however, before concentration becomes too great, otherwise the heat of reaction may become great enough to caramelize the sugars. A concentration of 20° to 25° Brix is not too high to cause any trouble in this respect, providing rapid agitation is maintained, as it is while the material is boiling in the evaporator.

Although it is always necessary to neutralize a portion of the acid present in citrus juices, certain other juices are sufficiently non-acid to be palatable when concentrated without acid adjustment. This is notably the case with certain varieties of apples and also with prunes. Carrots also require no neutralizing, in fact a more pleasing flavor is obtained if grapefruit juice or lemon juice is added to the carrot juice to increase the acidity up to about 0.75 percent to 1.0 percent.

When making Bruceet from carrots, there is a matter of starch that must be given attention. Starch is insoluble, but by the action of amylase it can be converted to maltose with a small percentage of dextrins remaining in the juice. For this conversion the proper enzyme must be chosen to insure a high degree of saccharification. Amylase from bacteria and molds will yield a high proportion of dextrines with low maltose, while amylase from malt under optimum conditions of temperature and pH yields relatively higher proportions of the sugar. Optimum temperature for the conversion is around 60° C. and the pH should be in the vicinity of 3.8. The progress of the conversion can be followed by means of the well-known iodine reaction, which gives a blue color with starch, and as the dextrines are converted the color reaction becomes green, then brown, red, and finally colorless. Too high a percentage of dextrines will prevent the formation of a hard Bruceet,

and the behavior of the material will be much the same as when the pectin has not been degraded. The maltose on the other hand will allow not only a hard Bruceet to form, but also will contribute a rich malty flavor to the carrot Bruceet which greatly enhances the natural flavor and appears to remove any objectionable raw carrot flavor.

To the finished Brucentrate is added SO_2 in the proportion of about 250 parts per million for the purpose of retarding oxidation during shipment and storage. Storage for more than a week or two is best maintained at low temperatures. In our pilot plant Brucentrate has been kept for more than a year at 40° F. without disastrous results due to oxidation.

The second stage in the manufacture of Bruceet is best carried out in a hard candy factory, since machinery for the manufacture of hard candy is readily adaptable to the finishing of Bruceet. For this process the Brucentrate is placed in the candy cooker and the vacuum brought up. Steam is then admitted to the jacket and the mass cooked until the proper temperature is attained. The finishing temperature is expressed not as a definite temperature, but as a certain number of degrees above the boiling point of water at the vacuum within the cooker. The higher the vacuum, the lower the finishing point will be. It is advantageous to keep the vacuum high so that it will be unnecessary to heat the Bruceet high enough to caramelize the sugars. The actual finishing point varies according to the raw material being used; for example, the finishing point of orange differs from the finishing point of grapefruit, and apple, pineapple, carrot, etc., all have finishing points characteristic of those products. The time necessary for the material to stay in the cooker will depend upon the characteristics of the cooker being used, but usually it is in the vicinity of 15 to 20 minutes.

As soon as the cook is finished, the vacuum is broken, and the hot material (which is in a plastic condition similar to hard candy in the same stage of manufacture) is run and scraped out upon a water jacketed table and from there is placed upon canvas rollers. These rollers shape the mass into a long cylinder from which the plastic Bruceet is passed through metal rolls which form the material into two of its final dimensions. The long rectangular strip is then cut into appropriate lengths, and, after it has cooled and become hard, it is ready for the wrapping machine. Wrapping and packaging are done in the accepted manner upon machinery available for the purpose.

Since Bruceet contains a high percentage of fruit sugars, it is extremely hygroscopic. Much attention must therefore be given to the wrapping material as well as to its sealing qualities, so that a high degree of moisture vapor impermeability may be assured.

HOW CALIFORNIA INSTITUTED SANITARY CONTROL IN FOOD PLANTS [1]

K. F. MEYER
George Williams Hooper Foundation, University of California, San Francisco, California

This paper presents in a thoughtful fashion some of the history of the procedures which California has found satisfactory in the sanitary control of food plants. Suggestions are made for others to follow in the institution of similar programs. It is interesting to note that the author recommends a strong emphasis on the "educational phases" of a sanitary program rather than "regulatory phases."

At the outset, it is only proper to correct certain misunderstandings which the title of this paper may have created. First, there is nothing new or revolutionary which can be contributed to the sanitation in food processing plants; it is only necessary to see that the rather commonplace facts of environmental sanitation are applied. Second, the word "control" implies police measures when in reality the sanitation program under discussion is built upon sound educational and organizational principles; this aspect may possibly be new. Third, the reference to a certain State on the West Coast unquestionably will give rise to a feeling of resentment, which may charitably be expressed by the usual lifting of the eyebrows. Still a young State, the home of a great deal of make-believe, it possesses, however, in matters of Public Health a keen sense of social consciousness. Ever since 1920 it has been embattled with the problems of sanitation, to protect from injurious spoilage the food which pours from its factories. The official health agency in closest cooperation with its chief consultant has explored and experimented on broad lines with various sanitation programs. Educational and, when needed, supervisory practices were introduced in order to safeguard the health of the consumer. Perhaps it is not mere coincidence that the food preserving industry recognized the limitations of the early supervisory program, which was voluntary, and entrusted to the State Department of Public Health the enforcement of the Cannery Act of 1925. The experience gained over the 25 years since the inception of the sanitation program furnished an invaluable store of knowledge which could be promptly mobilized when in 1945 attention was called to the lack of proper sanitation, and to the laissez-faire attitude which had insidiously crept into many food plants. This state of affairs became increasingly more apparent, erupting when the inspectors of the multitudinous supervisory agencies beheld at close hand the high pressure operations of preserving establishments. While the situation was acknowledged to be acute, it was at the same time appreciated that the newer concepts on sanitary theory and practice embodied in the Federal and State Pure Food Laws enacted in 1938 and 1939 awaited consummation. Immediate action was indicated, however, when test sampling surveys disclosed in some plants a deplorable lack of cleanliness. After a careful study of the methods best suited to detect insanitary food handling practices, the State Food and Drug Administrations once more set about the task of righting the wrongs in the processing plants.

Before a brief account is given of the food sanitation program as conceived and developed in the West, it may not be out of order to set forth certain general axiomatic concepts. A noteworthy feature of modern society is that its strength depends to an unprecedented extent upon the cooperation of its members; since the

[1] Presented before the Seventh Annual Food Conference, Boston, Mass., June 3, 1947.

specialist can live only through the help of others, cooperation is a necessary corollary of its members. The congested life in the cities of a complex society and, to an equal extent, the products of its fields, farms and waters which are often transported thousands of miles to the ultimate consumer, require careful attention to sanitation. Life in a world built by science and technology is possible only with widespread cooperation, in the field of health and elsewhere; the first essential in securing that cooperation is to develop the inherent desire of the people to work together. The most powerful method is to present the group involved with an inspiring objective. With an ideal, men and women lose themselves in working for the common good. Cooperation in a society of free people requires this will to work for the common welfare. "Without vision the people perish" applies with enormous force to the modern world. Whether the vision comes from political or economic expediency makes no difference so long as the will is there. It is these far-reaching considerations which have guided those responsible for the activation of the sanitation program in food preserving plants.

In the Preliminary Draft of a Sanitation Manual for Food Industries (University of California Press, 1946) the problem which confronted the food packing industry is presented as follows:

"Recognition has long been given to the principle that the public is entitled to protection from illness and death caused by consumption of impure foods. Initial regulatory efforts were directed mainly toward protection of food from contamination with pathogenic organisms or with other substances harmful to the health of the consumer. There also has developed a public consciousness, reflected by regulatory agencies, that in addition to protection of his health the consumer has the right to protection against practices violating hygienic decency—practices which are offenses only to his aesthetic sense.

"This conception of sanitary practice was incorporated in the Federal Food, Drug, and Cosmetic Act of 1938 which specifically states that 'a food shall be deemed to be adulterated if it consists in whole or in part of any filthy, putrid or decomposed substance or if it is otherwise unfit for food—or if it has been prepared, packed or held under insanitary conditions whereby it may have become contaminated with filth.' A cursory inspection of recent actions taken by the Food and Drug Administration under the Act will reveal that offenses against hygienic decency are cited in the libels in more than half the cases. In addition to avoiding conflict with the law, modern sanitary practices return considerable dividends in the long run through (1) improved quality and lower spoilage of the product, (2) better consumer acceptance, (3) less loss of time from accidents and from breakdown of equipment, and (4) greatly improved employee morale—decidedly important under present labor conditions.

"Some States have legislated for the regulation of canneries and are staffed to give inspectional services in this field. One of the early laws was Chapter 428, California Statutes of 1925: 'An Act to regulate the conduct of canneries, to create a Division of Cannery Inspection to carry on such regulations, to provide rules regulating the proper sanitation of canneries under the State Board of Health.' This Act, as amended to 1945 inclusive, reads in part:

'Sec. 9. The State Board of Public Health may, after notice and opportunity for hearing for the following cause or causes, suspend or revoke a license issued under this Act:

'(a) The non-payment of said pro rata share of the cost, or failure to comply with a demand for a cash deposit or other security by the holder of such license.

'(b) The non-compliance with any of the regulations of the State Board of Public Health.

'(c) After conviction for violation of the California Pure Foods Act (Health and Safety Code) the license may be suspended for a period of from one to 30 days.

'(d) The operation of an insanitary cannery after due notice by registered mail has been received.

'(e) Inadequate rat-proofing of a cannery throughout.

'(f) Wilful packing of any canned food commodity which has been rejected by a duly authorized agent of the State Department of Public Health.

'(g) The packing of any food commodity under the supervision of this Act without notifying the State Department of Public Health before packing same.'

"The California Health and Safety Code as amended by Stats. 1939, Ch. 731, and by Stats. 1941, Ch. 1149, reads in part:

'26470. A food shall be deemed adulterated: . . . (4) If it has been produced, prepared, packed or held under insanitary conditions whereby it may have become contaminated with filth, or whereby it may have been rendered diseased, unwholesome or injurious to health; . . . '

"Thus a new significance has been given to the sanitation of foods, and food processors can no longer be concerned only with obvious grossly insanitary conditions."

The broadened legal interpretation of the term "adulteration" found in various laws recently enacted further emphasizes that the existence of insanitary conditions during preparation and packing of food is inimical to the interests of our society, which has developed a strong aversion to filth. Filth is filth whether it is cooked or raw, safe or harmful, visible or invisible to the unaided eye. So much the worse if it is sometimes strong enough to affect the flavor or to offer difficulties in the ultimate safe preservation of the product. These facts were all well known and any intelligent reader could orient himself regarding the principles of plant sanitation by reading Chapter 2 of Food and Drug Circular No. 1 entitled "Microanalysis of Food and Drug Products." Yet, the first friendly warning by the Food and Drug officials that food manufacturers who through insanitary practice invited the contamination of their products with rodent hairs, insect parts or even excreta, might be subject to seizure and even criminal prosecution, called forth an immediate reaction.

The Western group of food preservers, who in the past had learned to appreciate the significance of these warnings, promptly instructed their Technical Committee to develop a sanitation program. There was never any doubt in their mind that sanitation is fundamental to food production. It was merely a question of how to achieve a proper balance between production and sanitation; how to implement the requirements set down by law; how to develop an effective approach to the problems. In consultation with representatives and consultants to the State Health Department and the School of Public Health of the University of California three important decisions were made: (1) To assign the sanitary inspection of food preserving plants to sanitarians. (2) To make a survey of the existing conditions. (3) to develop special courses of instruction.

The decision to select sanitarians to supervise plant sanitation operations was motivated by a number of facts. For the past ten years a number of energetic and enthusiastic young men had been trained in environmental sanitation. Many had University degrees and through hard and continuous training on the job had achieved a state of proficiency and standards of technical training which were recognized in the legislative action which licensed them. The majority of these registered sanitarians had chosen a career in public service; they were keen observers and technicians, with an ability to educate people in the better methods of sanitation. The public knew that recommendations made by them were not arbitrary rules, but proposals given in the best interest of the persons concerned. Quite a number had specialized in the supervision of food handling establishments, and all were acquainted with the problems of housing, waste disposal, etc.

With all of these qualifications, and a background in the biological and social sciences these professional sanitarians were felt to be eminently well equipped to develop effectively the sanitation in food plants. There is no basis for the fear that they will not consult the public health engineer when necessary. Moreover, it should be pointed out that at least in the West, a sanitarian is able to assume educational, inspectional, and law enforcement work without the expenditure of six to seven years required in training a well qualified public health engineer. This point must be made clear in view of the constant claims by certain groups that all sanitation or environmental control falls within the field of engineering. The training of sani-

tarians as now adopted by certain schools of public health provides a form of education in the basic sciences and administration which has notably promoted good public health in many areas and social units economically incapable of supporting a public health engineer. The performance of the sanitarians during the past year has amply justified the faith placed in their ability to do constructive and effective work in the food plants.

The next step in the planning was the sanitary survey of the plants. It was the purpose of these surveys "to look" and to draw conclusions based on the facts obtained by observation. Since the time when health surveys and appraisals were first introduced by Chadwick in 1842 in England, and in 1850 by Lemuel Shattuck in Massachusetts, the principles and technics have been in the process of crystallization, until now they are formalized. They serve as an excellent background for educational campaigns, and often have led to noteworthy improvements in milk and school sanitation. Historically, it is significant that the Russell Sage Foundation sponsored numerous health surveys prior to 1920, while 25 years later the National Canners Association created interest in its plant sanitation program through the medium of surveys. In fact, it was only after significant findings secured through the medium of the surveys were available that the food preserving industry of the West inaugurated on April 1, 1945 the program to improve the sanitation of the plants individually, and thereby the industry as a whole. The early, somewhat casual, entirely voluntary surveys pointedly disclosed:

(1) That in every plant environmental conditions conducive to the contamination of the food existed.

(2) That rodent infestation due to unrecognized harborage and lack of ratproofing was common.

(3) That little or no attention had been paid to the protection of sugar and spices from rodents and insects (ants, flies, bees, etc.).

(4) That contamination of the final product with dirt and filth on the outside of the containers in which ingredients were stored was not uncommon.

(5) That overhead moisture condensation from the roof and from overhead pipes and beams not only was conducive to mold growth, but through dripping carried dust and dirt to the product in the course of processing.

(6) That overhead beams often served as rat runways.

(7) That the maintenance of mixing vats below the general floor level encouraged extraneous contamination.

(8) That in some instances no adequate precautions to prevent the entering of harmful material into the food had been taken.

(9) That walkways over the food being prepared favored contamination of the product by material from the shoes of the workmen.

(10) That the water entering the plant was not always of a sanitary quality.

(11) That the clean-up procedures for belts, conveyors, vats, containers left a great deal to be desired.

(12) That only too often lack of adequate lighting, both as to location and intensity, was responsible for the progressive collection of dirt and waste in dark corners and under machinery.

(13) That the construction of the exhaust boxes favored undesirable contamination.

(14) That the sanitary facilities and comforts for employees were in no way suited to impress upon the personnel the desire for cleanliness.

(15) That the management was not aware of the fact that good housekeeping means sanitation, which in turn is a good investment.

(16) That progress can only be made provided in each plant a trained and competent person with authority is made responsible for the administration of the sanitation program.

In view of these facts, two approaches to the solution of the problem suggested themselves: (a) Through legislative action, or (b) through education. Previous experience had amply proved that with very few exceptions neglect in matters of sanitation invariably could be attributed to lack of information or advice, and rarely to a deliberate intent to violate sound principles. During the past twenty years more progress has been made through educational than through supervisoral action. The sanitation program as planned in 1945 and as it now functions is entirely devoted to this principle.

The findings of the surveys with appropriate recommendations are incorporated in confidential reports to the management. These surveys have been of inestimable value to the food processors. In fact, the response to this type of service has been most gratifying, so that in 1946 over two hundred such surveys were conducted throughout the Western States and Alaska. Many of the executives refer now with pride to the improvements they have already made, and express a deep conviction that the sanitation program has improved the quality of the product, reduced spoilage, improved production, and consequently added greatly to the competitive advantages. They likewise record economic advantages in reduced insurance rates, and as a result of the consideration given to the welfare of the employees, better quality of output and higher efficiency of the workers.

The original sanitary survey form has been revised. It is a very detailed questionnaire and in view of the experience gained during 1946 is now designed to suit most operations. The use of this questionnaire is highly recommended, since honest answers to the questions will invariably disclose conditions which had been overlooked. Moreover, a study of the survey form will promptly develop a new point of view; the food preserver will be made conscious of the intricacies inherent to the sanitation program, and the necessity for obtaining expert advice regarding technical and operational details. Specific improvements must be made by the individual processor with the guidance of technicians, who can in an unobtrusive way promote and sell the benefits of sanitation. Sanitation Circular No. 2 published in March, 1946 by the National Canners Association is available to any interested processor.

The third phase of the plan of plant sanitation envisioned the selection by the processors of a qualified person to be responsible for the guidance and supervision of the work in each establishment. There will probably never be available an adequate supply of trained sanitarians to assume this function. It was therefore decided to train, in sanitation, personnel already familiar with the operations of the food industry. At the request of the National Canners Association, the University of California School of Public Health offered in the Fall of 1945 a special training course in food industry sanitation. The intensive course was of eight weeks duration, with enrollment limited to twenty-five applicants recommended by various establishments. Twenty-three men connected with the food industry in various sections of the United States completed the course of instruction, which consisted of lectures by experts, seminars, and field demonstrations. In the group of twenty-three trainees were three State inspectors, one from Florida and two from California. Reports concerning their successful activities during the past year attest to the value of the educational aspect of the sanitation program.

In designing and organizing the course Mr. Walter S. Mangold, Associate Professor of Public Health, University of California, realized the necessity for developing a Sanitation Manual, which could be used both as text and reference.

In the foreword to the Preliminary Draft of a Sanitation Manual for Food Industries Professor Mangold outlines the evolution of the text as follows:

"Because of the shortness of time and the heavy daily schedule, it was foreseen that only an elementary approach could be expected. However, it proved to be an excellent class exercise, obliging the students to digest the fundamentals of sanitation and to apply them in a practical manner.

"The need of a Manual was discussed in class and a committee was elected to work over the chapter outlines and subheadings. The proposed outline was again discussed; then two students were assigned to the preparation and presentation of each chapter. An essay form of presentation was preferred, but certain groups believed that their subjects could be presented best in outline, and this was permitted. During the final week, the progress of the Manual stimulated much discussion, which resulted in numerous revisions before the papers were finally submitted.

"It is hoped that this limited class project will instigate further study and result in the drafting of a finished Manual."

This Manual, incomplete and elementary though it is, represents in condensed form the best information available at the present time. The demand for it amply reflects the great interest in plant sanitation: the original printing of 3,000 copies was sold in six weeks (October 1, 1946), and of the second printing of 1,500 copies, an additional 600 had been distributed by April 1, 1947. Sections of the Manual have been reprinted in *The Canning Trade*.

The men who completed the eight weeks course in sanitation at the University of California in the Fall of 1945 have held two meetings since then, one in November, 1946 and in May, 1947. At the November meeting the group went on record as desiring to form themselves into a non-profit professional association of food industry sanitarians for the purpose of maintaining and improving the high sanitation standards in the canning, freezing, dehydrating and other food processing industries throughout the United States and its territories. At the meeting held in May the group adopted a constitution, forming themselves into an organization known as "The Association of Food Industry Sanitarians." At this meeting there was considerable discussion by the group of revising the preliminary Manual and a Publications Committee was appointed. It was decided to re-write the Manual. Certain individuals were assigned subjects, with the understanding that each person should enlist every aid necessary in writing or preparing his material. A deadline for drafting the material was set as November, at which time it is planned to have an open discussion of each subject.

Preceding the training course meetings to acquaint the executives of the food plants were held in the Western area. No one who sensed the importance of these meetings and the first course could leave without a full realization that merely a beginning had been made, and that a vigorous effort must be made to reach a larger group of food preservers. With this in mind, 15 two-day conferences given during the Spring of 1946 were designed to reach key personnel in canneries, such as superintendents, foremen, supervisory personnel and clean-up crews. Intensive discussion was stimulated by visual aid material, such as posters, photographic slides and film strips. The more detailed portions of the didactic material used was assembled in a mimeographed pamphlet entitled "Outline Material, Conference on Food Plant Sanitation." A mere glance at the pages discloses the rapid advances which have been made by the sanitarians and instructors in developing the educational aspects. The purpose of these conferences which were held in the principal canning centers in the Northwest, Utah and Colorado was to create interest in sanitation, and to make the conferees "sanitation conscious." By pointing out the frequent general unsanitary conditions in the industry, a desire to carry out a constructive sanitation program was motivated. These conferences had a strong appeal

to the management, the mechanics, clean-up men, etc. Those in attendance were impressed with the basic truth that they were engaged in the honorable profession of producing and preserving food for human consumption, and that food must be stored, handled and preserved under the conditions of an attractive and highly sanitary kitchen. Those in charge of the conferences were deeply impressed by the interest and the seriousness with which the presentation of the factual material was followed. Over 980 persons, including representatives from newspapers, educational institutions, detergent manufacturers, government agencies, the pest control industry, dried fruit companies, etc. were in attendance. As a follow-up to these activities here outlined two-week short courses were held in San Francisco in December, 1946 and February and March, 1947. They were the logical sequel to the more intensive course. Most gratifying is the fact that these courses have been attended by men of extensive experience, well versed in the problems of the canning and food preserving industry. They participated with enthusiasm and never lagging interest in the grinding schedule of the discussions. The influence of this type of training is awaited with interest.

In order to keep the industry and those concerned with plant sanitation constantly in touch with recent developments and to enhance the esprit de corps, a one page mimeographed periodical entitled "The Conveyor" is being distributed under the sponsorship of the Western Branch Laboratory of the National Canners Association. To date, the three issues which have appeared in print show a deep rooted interest to render service, and to make plant sanitation an integral part of the every day processing procedures.

Those who have witnessed the evolution of this well thought out educational program are proud of the National Canners Association, which has always pioneered in newer methods, seeking to advance the welfare of its members. An active industry wide sanitation program humbly conceived in the West is now in progress in the East and Middle West. Two-day conferences have been held in seven States, and others are planned in order to cover the other sections. What is, however, more significant is that the democratic spirit which permeates the organization has always extended to non-members the benefits which issue from the fine cooperation of its members. A study of this pattern of cooperation, its framework and functioning is highly recommended to the preserving industry as a whole, and deserves more widespread study and appreciation.

These preliminary successes, however, should not create a false feeling of achievement. For the sanitation principles now being taught and carried into operation are based upon knowledge and scientific facts discovered and made available 30-40 years ago. In public health it usually takes half a century before scientific discoveries are applied to the welfare of society. There are today certain barriers to real progress in sanitation which must go down, before advances fundamental to that progress can be made. It is only proper to mention a few of these problems. New types of architectural designs must replace the medieval makeshifts of buildings which with the best of intentions and many pounds of new paint cannot be adapted to clean food production. In any future construction of preserving plants, the sanitation hazards must be taken into consideration and must be scientifically planned for. This immediately raises certain pertinent economic questions. Although many plants have already reported tangible financial advantages from their sanitation program in a competitive economy, the cost analysis of the undertaking represents a powerful factor. It is anticipated that such studies will be carried out in plants of various sizes and the results made available. Little information can be gleaned from the published records concerning the requirements for adequate and

proper lighting in preserving plants. In fact, no scientific investigations had been made until recently when the Illuminating Engineering Society assumed the leadership in directing the work of a fellowship established by the National Canners Association at Stanford University. Research on fungicidal paints and the materials and procedures used in plant clean-up, including chlorination studies with respect to efficiency, corrosion and off-flavors, has been singularly deficient. An excellent opportunity for basic as well as applied research is afforded the manufacturers of such chemicals to find their proper and safe use in food plants. Cooperation in these technological aspects will lead to an ultimate solution of certain important problems. The question of whether or not bacteriological surveys add positively to the scientific appraisal of some sanitary practices in food plants requires critical and unbiased investigation. There is no need to reiterate the well known fact that quantitative estimation of bacterial contamination merely attests to the existence of a given state of affairs at the moment the sample has been taken, and that such examination gives no assurance that the count may have been higher or lower before or after the sampling. A slavish fetish to check operations with the aid of the microscope, though educationally valuable, has frequently been followed by neglect of basic principles and serious consequences when the laboratory—only too often manned by unqualified personnel—reports a low figure. Along this line experience during the years has proved that a well regulated and continuous plant sanitation program adjusted to the capacity of the equipment and personnel will greatly aid in keeping the mold count of tomato products below the official figure. The daily microscopic sampling, as a rule, contributes little, particularly when the analyst for economic reasons is called upon to study dozens of specimens.

Little is known concerning the fatigue factor in the preserving personnel and the influence it may have on the daily clean-up job which is part of a sanitation program. Studies in industrial hygiene, combining research in the physiology of work with a psychological appraisal of the response of employees to sanitation programs are in order. How far does the housekeeping in the plants affect the workers? Does it influence cleanliness and the self respect of those who are ultimately the group on which the success or failure of the sanitation program depends? One would like to know.

Even in the field of rodent control one is faced with many unknown factors. Granted rat-proofing will keep the rats from the interior of the plant, and that a poisoning program should render the plant free from rodents. It must be remembered, however, that new avenues of ingress will be found by these intelligent animals. A group of mammologists of the Hooper Foundation has diligently studied this aspect of the rat problem, and soon expects to make recommendations with respect to the policy which a cannery must follow. It is quite apparent that the available rodent control services leave a great deal to be desired.

Finally, it requires little imagination to realize that a sanitation program as outlined requires that a well staffed and well equipped consultation service always be at hand. Continuous follow-up work is imperative and newer knowledge must be interpreted and distributed. It is reassuring to know that the insanitary state of food plants is remediable and that ultimately the problems can be conquered, since the essential methods are basically simple and eminently satisfactory provided constant appraisals maintain the cleaning service at the highest level.

This thought leads to the question: Which of the two methods of handling a sanitation program is more effective, the "educational" or the "regulatory"? The history of the legal regulations governing the food industry shows that they were in the past always directed toward the prevention of food adulterations, which had

their roots in fraud and not in health. Regulations dealing with particular foods such as milk and bread became necessary long before attempts at general regulation of the entire food supply was instituted by the local or State health officers. This step became necessary when the consumer requested assurance as to the purity and safety of his food. In States in which the production and preservation of foods are a part of the economic structure, regulatory supervision has always been deemed necessary. California has freely experimented. It was the first State in the Union to adopt the Pure Food and Drug Act of June, 1906, one year after its passage on March 11, 1907. A uniform Food, Drug and Cosmetic Act modeled after the Federal law was made a part of the legal obligations of the Bureau of Food and Drug Inspection on January 1, 1939. However, the State continues to be in a unique position with regard to regulatory provisions through the adoption of the Act to Regulate the Conduct of Canneries in 1925. Aside from providing compulsory licensing and inspection of commercial canners packing non-acid food products, it provided for the development of the technical procedures of the sanitation program through research and plant studies. Through the years the administration of this Act has offered innumerable opportunities to study the most effective ways of applying science to technology.

The supervisory official responsible for its administration, instead of acting as a police officer hiding behind the power of the law, issuing arbitrary orders from his desk, soon realized that the educational approach not only achieved much better results, but promoted more enthusiastic cooperation and integration. A food processor who knows the scientific and economic reasons why he should follow certain regulations can offer valuable technical suggestions to the sanitarian. Policies mutually agreed upon at the conference table by representatives of the Health Department and its technical consultants together with the technical committees of the Food Preserving Industry have an overwhelming influence on the success or failure of the contemplated enforcement of a regulatory procedure. Early in the enforcement of the Act the leaders in the Industry recognized their obligation to the small, insecure food packer. They liberally contributed to, and in fact, entirely carried the research program themselves and thus reduced the operating costs of this group. They always have believed in and defended the principle of self-policing. Thus, instead of being ruthlessly regulatory and supervisory, the administration of the California Pure Foods Act and its redundant legal ancillaries has under just and considerate guidance become an education forum. It was in this kind of an atmosphere—one of mutual trust—that the policies of the programs of plant sanitation were planned, and the activities entered into conjointly with the State were incorporated, broadened and developed.

Under the impact of World War II all food processing establishments were called upon as a part of the War effort to produce quantities of foodstuffs far in excess of their normal capacity. Inexperienced employees, the impossibility of obtaining new equipment or materials for repairs, and an inadequate supervision created conditions which made the maintenance of sanitation a problem of considerable magnitude. A survey in 1945 disclosed the following factors contributory to the insanitary state of food plants: (1) Obsolete construction of some food establishments. (2) Obsolete, worn out equipment. (3) Contamination by dust, dirt, flies and rodent infestation. In the course of 205 inspection surveys the sanitarian contacted the cannery personnel and the management. As a public educator he discussed the faults and violations of the Food Act. Being a trained man, he had the respect of nearly everybody. The details of each survey were transmitted to the management in an official but confidential letter setting forth the

findings with respect to insanitary conditions, and recommending immediate action to correct the deficiencies. With few exceptions, invariably small establishments, the response was most gratifying.

Re-inspection has shown that throughout California the sanitary operation of food plants is uppermost in the mind of the management and personnel. The eagerness to become educated and to be trained in the approved procedures is remarkable. Among the improvements noted may be listed: Clean sanitary water, elimination of wooden cannery equipment, re-surfacing of worn concrete floors, new and additional floor drains and waste disposal systems, elimination of potential sources of contamination in overhead construction, insect screening and rat-proofing, better lighting, closed rooms for raw products and ingredients, more suitable storage of equipment, better welfare facilities for the workers, plant cleaning during meal times and rest periods, thorough cleaning of equipment at the end of processing, etc. In the fish packing plants the improvements are continuing, conspicuous perhaps because here conditions were most acute, largely due to the nature of the raw products. The water used for fish fluming still leaves a great deal to be desired. Well water may displace the present contaminated supply; other sources are being explored and experiments with chlorination are in progress.

This sketchy account reviews the blending of educational and regulatory policies adopted to promote the welfare of the food processors and protect the health of the people. It is the story of the unique coordination between a Research Institute which pioneered in certain processing problems, an adventurous health organization dependent on scientific facts, and a progressive and cooperative group of industrialists, the National Canners Association. It is in a very real sense a story of achievement. Since the policies have been tested on a fairly large scale, their adoption can be unhesitantly recommended. The pace of the improvements has been accelerated by the constant presence of an inspector, whose main function is to supervise the handling of the raw materials and the processing procedures in pressure retorts. In the course of his daily inspections of the food plants he has an opportunity to point out inadequacies in the execution of the sanitation program, and to recommend corrections. Several processors have voluntarily closed their plants and thoroughly renovated them before resuming operation. Occasionally, it has become mandatory to refuse permission to operate until the premises and equipment had been renovated. In rare instances a recalcitrant processor has had to be cited to a hearing before the Chief of the Bureau of Foods and Drugs, or before the local District Attorney's Office when his response to the educational policy was one of indifference.

For years, in California, the owners of every type of food establishment imaginable, from alimentary paste plants to drying and juicing plants, and those processing frozen foods or devoted to walnut shelling have operated with due consideration to sanitary objectives, proper housekeeping, etc. Most processors long ago realized that these principles improve the quality of the product, increase efficiency of operation, and make for greater competence and interest on the part of the worker; this in turn results in greater consumer acceptance of the product, and a consequent greater profit to the packer. To set an example is very important. The wisdom of the enlightened packers cannot help but affect the industry as a whole.

IMPROVING SANITATION THROUGH EQUIPMENT DESIGN[1]

H. E. KINGMAN, JR.
Wilson & Co., Inc., Chicago, Illinois

(REVIEW PAPER)

The need for sound sanitary practices for meat products which rank first in the nation in total value is emphasized. Sanitary practices in Federally inspected plants are discussed. Elements of plant construction and suitable materials for equipment are reviewed. There is a constant need for research, education, and the application of new knowledge to the control of the industry.

Sanitation is a subject that has been given a great deal of attention during the growth and development of meat processing. In meat packing plants the daily cleanup of rooms and equipment used in the preparation and handling of food products is of prime importance. Sanitation also exerts a determining influence upon the welfare of the entire Livestock and Meat Industry.

There are, we all realize, certain fundamental sanitary measures that apply to all food processing plants. The meat packing field, however, encounters problems in sanitation that are peculiar to this industry alone.

So that the various ramifications of sanitary control in this particular field will be fully appreciated, it is necessary to spend a few minutes describing the characteristics of meat packing and the conditions which affect operations, and also mention a few seemingly unrelated factors that exert a tremendous influence on this business.

During peace time meat packing ranks first in the nation in the total value of products manufactured. The ten year average production of the meat packing industry from 1929 to 1939 amounted to 2½ billion dollars worth of product.

Meat is the largest single item in our food budget. Of every dollar we spend for food, 35c goes for meat products and fish. We spend about three times as much of our food dollar for meats and fish as we do for either fresh fruit or vegetables or for flour, bread, and cereal products.

Likewise, more than one-fourth of the American farm total cash income in 1945 came from the sale of meat animals. In 1945, which was one of the largest years on record, farmers and ranchers received approximately five billion dollars from the sale of meat animals.

Of the meat packer's sales dollar, 76c is spent for livestock or raw materials, 13c for labor, 7c for depreciation and repairs, 3c for taxes, and approximately 1 penny is net profit. The operating margin in the meat packing business is extremely narrow, yet the volume of production is tremendous.

The profit expected as a result of the sale of 500,000 pounds of product can be completely wiped out through the waste or spoilage of 2500 pounds of beef at prevailing prices. In other words, each 1 pound of spoilage cancels any profit on 200 pounds of product.

Under these circumstances sanitation becomes increasingly important.

As mentioned, the major function of the industry is to convert the supply of meat animals marketed by farmers into meat and other products desired by consumers. Our leading products are highly perishable, and as a result, many operations are carried on under refrigeration.

---

[1] Presented before the Seventh Annual Food Conference, Boston, Mass., June 3, 1947.

This means that working areas in the plants are kept at as low a temperature as our workers can tolerate. Low temperature will retard bacterial growth, however, considerable attention must be given to keeping original bacterial counts at a minimum. Refrigerated rooms also present certain cleanup problems, since it is quite difficult to use steam or hot water to wash down walls or floors in these areas.

We do use steam in refrigerated rooms, but we do so at great expense and confine this type of cleanup to stationary equipment.

Meat packing is primarily a disassembly process, wherein the manufacturing operation starts with a complete unit which is progressively broken down into its component parts, various parts then being subjected to divergent processing operations.

Beef and pork are the leading products of the industry, with veal, lamb, mutton, and a wide range of by-products also contributing to sales. Most beef, veal, and lamb, is dressed and offered for consumption as "fresh" meat within about ten days.

On the other hand, pork is subjected to a number of varying processes. The loins are "pulled." Hams, shoulders, fat backs, and bacon bellies are handled as primal cuts, with the fats being rendered into lard or shortening. These items can be cured and smoked, converted into sausage, canned or packed in vinegar and enclosed in a glass jar.

This product gets to the consumer's kitchen in much the same form that it leaves our plant. We must, therefore, have as our ideal, "kitchen-cleanliness" in all our operations.

By-products of meat packing ranging from leather goods to animal feeds and pharmaceuticals, have become increasingly important in the overall operations, particularly of the larger packers during the past twenty-five years. Interest in by-products was stimulated at an early date by sewage disposal problems, especially for slaughtering establishments located in large population centers. By processing some of the "waste materials" into useful items, the magnitude of the sewage disposal problem was reduced. In more recent years, technological advances have opened the way to higher value uses for some of the by-product items, particularly in the utilization of pelts and some of the animal glands.

Large daily variations in slaughtering operations are common in the meat packing industry, necessitating flexible planning and operations. In addition, there are seasonal variations in the marketing of livestock, with the marketing of hogs normally reaching a peak for the year in December-January, and a low point in August-September, whereas cattle and sheep usually reach peak volumes in October, and a low point in late winter, or early spring.

Another important factor which influences our operations, is the fact that packing plants which distribute their products in Interstate Commerce must comply with certain Federal regulations, dating from the Meat Inspection Act of 1906, pertaining to the health of animals slaughtered, sanitary conditions in the plants, processing practices employed, and similar matters. At the beginning of 1945, there were 477 establishments conducting slaughter under Federal inspection, accounting for possibly 15% to 20% of the total number of commercial meat packers. These establishments average larger in size than the non-Federally inspected ones, and are estimated to have produced 73% of the total production of meats in the United States in 1944.

This inspection is carried on at three levels—(1) An examination of the meat animals by veterinarians before slaughter to dispose of those unfit for edible purposes before they get to the killing floor. (2) A postmortem examination of the carcass and viscera by veterinarians to determine if the animal had some condition or disease that could not be detected in the live animal which, however, would make the meat

unsuitable as a food product. (3) A continuous inspection of the processing facilities and technique by lay inspectors to be sure sanitary procedures are followed rigidly.

These are some of the "internal" characteristics of the meat packing industry. The management of an individual packing plant fully aware of the routine problems which must be faced can plan its operations and build its organization accordingly. It is in this field that improved equipment design has been of the most value.

The first point I would like to discuss as a part of equipment design is general building construction. In the meat packing industry, all proposed new construction, or modifications of existing buildings, must be presented to the Washington office of the Meat Inspection Division in the form of blue prints drawn to one-fourth scale and accompanied by complete specifications. These plans are closely scrutinized and approval is given only after all sanitary requirements have been fulfilled.

One of the fundamental considerations is the provision of sufficient floor space to prevent congestion. This is especially important in slaughtering departments to avoid contact of diseased with healthy carcasses and of contact of unskinned or partially skinned calf and sheep carcasses with exposed surfaces of skinned or partially skinned carcasses.

In the slaughtering of cattle, these animals are stunned before bleeding, and it has been found advisable to provide a dry area, at least 5′ wide in front of the stunning pen, for receiving animals. This area is separately drained and sufficiently removed from the bleeding area.

The bleeding area is curbed, and so located that blood will not be splashed on stunned animals lying on the dry area or upon carcasses being skinned on the dressing floor.

An area 16′ x 8′, or 128 square feet of floor space, is provided for the preliminary cattle skinning operations, evisceration of carcasses, trucking of product, and for whatever inspections are made at this point on the cattle slaughtering floor. An additional area, at least 14′ x 8′ in dimension, is provided for each carcass to finish the skinning operations. Carcasses are suspended by trolleys from rails during most of the slaughtering and dressing operation. It is quite important that these rails be of sufficient height to prevent carcasses from coming in contact with the floor.

The bleeding rail for cattle is 16′ above the high point of the floor. This is necessary since the animal is suspended by a shackle approximately 48″ long, and at this time, during the dressing operations, the head is still on the carcass. After the head is removed and the beef carcass is transferred to a trolley, the height of the rail throughout the slaughtering department, and in the coolers, is 11′.

Dressing conveyors, for beef slaughtering, must be at least 4′ apart, and for hogs and small stock, at least 2′ between rails, and 2′ away from walls, posts, and other obstructions.

To promote good sanitation, floors, walls and ceilings in all departments are constructed of material that can be readily kept clean.

Floors requiring drainage are constructed of impervious material, such as dense concrete or vitrified floor brick of good quality, laid on a concrete base. Interior wall and ceiling surfaces are smooth and flat and composed of portland cement plaster or other non-absorbent material. Ceilings should be of good height, about 10′ or more, and to avoid damage to glass in windows, from the impact of hand trucks, the window sill should be at least 3′ above the floor. Window sills are sloped about 40 degrees to promote sanitation. We find that brick is the most desirable floor material, and glazed tile is being used more extensively for walls. The good appearance and sanitary features of tile walls more than offset their initial cost.

All parts of floors where wet operations are conducted must be well drained. The slope of about ¼" a foot to drainage inlets is desirable for usual conditions. To avoid accidents, excessively smooth floors should be avoided. Good results have been obtained by laying concrete floors with a topping containing hard particles such as carborundum, so as to afford a good foothold. Each floor drain, including blood drains, is equipped with a deep seal trap and properly vented to the outside air. Floor drainage valleys, about 24" in width, and integral with the floor, are required under the dressing rails for hogs, sheep, and calves.

In the slaughtering departments at meat packing plants, we are confronted with the problem of disposing of inedible material and in planning for adequate sanitary control; due consideration must be given to providing space and in the arrangement of buildings so that these inedible departments will not interfere with edible operations, or create objectionable conditions. Inedible products departments must be separate and distinct from those used for edible products, except that the tank charging room of the inedible products rendering department is allowed one connecting doorway from the slaughtering or viscera separating departments. The arrangement of the inedible products tank house should be such that material is mechanically elevated to an upper level and gravitated to rendering units on a lower level. At least 2 rendering units should be provided for the prompt disposal of condemned and inedible material in case of breakdown of one of the units.

Waste material, such as paunch contents, hog hair, blood, and pen manure, must be disposed of without creating objectionable conditions, and in submitting plans for new construction or modification of existing buildings, notations are always made regarding these features.

In the slaughtering of hogs, dehairing and cleaning machines have been developed to do this job with a minimum of labor. Scalding at 140 degrees F. is still the accepted method of softening hair and scurf in hog slaughtering, and there has been added to this a rosin depilatory process, which consists of immersing the entire carcass in a bath of hot rosin. After cooling, the rosin is peeled off, taking with it hair and hair roots, which were missed in the regular dehairing machines. The high temperature of the rosin bath undoubtedly gives some beneficial sterilizing action on the skin surface.

Tables for handling internal organs are constructed of stainless steel, and these tables are designed so they can be easily cleaned. In fact, moving viscera inspection tables are washed and sterilized at each revolution. Cattle and calf heads are removed from carcasses early in the slaughtering operation and are flushed and washed in specially designed cabinets before being placed on inspection conveyors. Suitable automatic facilities for sterilizing head hooks in scalding hot water must be provided. Trucks used for edible products are designed with 2" radius corners and are constructed of either galvanized metal or stainless steel.

Tables are constructed of stainless steel with perforated tops and hemmed edges to eliminate pockets or crevices where dirt or grease could accumulate.

Tables must be constructed to fit the particular operation performed. The height of tables will of course vary, but should be positioned so that the workers platform is 34" below the top of the table. There are a wide variety in types of tables throughout the meat packing industry. Nearly all of them are designed for specific jobs. For example, we provide tables within the slaughtering departments for the separating of the viscera of the various species of animals slaughtered. The cattle paunch emptying table should be equipped with a power operated lift, when evisceration is accomplished into trucks. The top of the table should extend over the

emptying hopper about 12″ and the sides of the hopper should extend down vertically below the top of the table, at least 3′ to avoid soiling the paunches.

Likewise, in our industry, there are a great many knife operations, such as trimming and boning in which it is necessary to have wooden cutting boards. These boards must be of hard wood or impervious plastic materials, and of course must be removable so they can be placed in sterilizing cabinets for cleaning and sterilization.

We use tremendous volumes of water in the meat packing industry. Some 500 gallons per head of cattle slaughtered. This means about 4 pounds of water for each pound of meat produced. Equipment wasting water, such as soaking and cooking vats, and sausage stuffing tables is installed so that waste water is delivered into the drainage system without flowing over the floor. Soaking and cooking vats are provided with overflow pipes, at least 2″ in diameter. The upper end of each overflow pipe is equipped with an open end cleanout tee to facilitate cleaning. Stationery equipment, and equipment not readily movable is placed at least 12″ from floors, walls, posts, and other fixed parts of the building, and from other equipment, to facilitate ready cleaning of outer surfaces. Vent stacks from covered cooking vats should be so arranged to preclude drainage of condensate back into vats. Equipment which uses water is installed so there will be no back siphonage of water into supply lines.

A separate washroom or area, should be provided for cleaning curing vats and trucks, utensils and containers, such as boxes and trays. The room or area should have adequate, direct, natural light and ventilation, impervious, well drained floors, and impervious walls and ceilings.

Conveniently located hand washing facilities are provided for the use of employees and inspectors. Each lavatory is supplied with hot and cold running water, delivered through a combination mixing faucet with outlet about 12″ above the rim of the bowl, to facilitate washing arms as well as hands. Liquid soap should be provided in a suitable dispenser and an ample supply of sanitary towels, and a suitable receptacle for used towels. Lavatories in workrooms should be foot pedal operated.

Sterilizers for knives, cleavers, and other implements are provided adjoining the lavatories, where required. These sterilizing receptacles should be constructed of rust resisting metal and should be of sufficient size for complete immersion of the implements in scalding hot water. Each sterilizing receptacle should be provided with a water line, a steam line, an overflow, and facilities for completely emptying the receptacle.

Sausage stuffers, grinders, canned meat fillers, chutes, and pipe lines, are designed so they can be completely dissembled and thoroughly cleaned after each day's operation.

Black iron, or steel, has very limited usefulness for the obvious reason that rust which soon develops in moist rooms very quickly makes such material unsightly, and almost impossible to keep clean. Iron or steel when galvanized or coated with tin resists rust for a considerable length of time, and is comparatively easy to clean. However, there is the ultimate necessity for regalvanizing or retinning at intervals, as the surface wears. Brine and salt meats coming in contact with such surfaces, particularly the galvanized metal cause considerable corrosion which adds to the difficulties of cleaning.

Sheet metal coverings on side walls, posts, tops of wood tables, the inner surfaces of meat handling trucks, meat chutes, and curing and cooking containers have proved very unsatisfactory from the standpoint of sanitary maintenance, and are not

acceptable to the Federal Meat Inspection Division. The use of angle iron in conveyors is not recommended. It's angles are difficult to clean, in the straight sections, and extremely difficult to clean at the joints. Tubular sections are more sanitary, and provide greater strength per unit of weight. Welding of joints also creates more sanitary conditions through elimination of crevices.

These are routine matters to us now, and possibly we have become so sanitation-minded throughout the years that we take it just as a matter of course throughout our plants in designing new equipment, and re-designing old methods in having the very best in sanitary control.

Mention must be made here of the outstanding accomplishments of the Meat Inspection Division, U. S. Bureau of Animal Industry. This organization has worked quite closely with us in developing a great many of the sanitary improvements in our industry. The meat inspection regulations have been based on sound, sanitary principles. The enforcement of these regulations has been accomplished through co-operation and a full realization upon the part of both management and government that we have the same objectives and ideals. There is no question but what the meat packing industry, at least that part of it which operates under Federal inspection, occupies an enviable position with respect to sanitary control, because of the progressive influence exerted through Federal meat inspection.

I mentioned briefly, some of the sanitation problems, which adequate planning and improved design can control. In our industry, we have a second group of sanitation problems with which we are constantly confronted, and as yet, have not completely eliminated.

It must be kept in mind that meat packing is not an independent industry. It is one segment of the broad livestock and meat industry. We receive our raw materials from producers, ranchers, and farmers, across the nation. Their problems become our problems as we process their animals into meat and meat food products. We feel quite strongly that sanitation cannot be confined to the four walls of a factory, but that for complete success it must be practiced on all levels of our industry. One of the basic premises of sanitation is the protection of human health. This part of our sanitation work is of tremendous importance. As food technologists, our principal responsibilities are to safeguard, protect, and promote the health of 140,000,000 American consumers. True, we are also interested in improving quality, acceptability, and palatability of our products. We are concerned with increasing the efficiency of operations, of reducing operating costs, but these are all secondary to the first requirement of public health.

In our industry we occasionally receive animals at the various markets that are not only unfit for human food, but actually constitute public health hazards, if not properly handled. Animals may be affected with tuberculosis, anthrax, septicemia, swine erysipelas, beef or pork measles, or other toxic conditions that would make their flesh unfit for human consumption. The carcasses and parts of these animals must be disposed of without excessive handling, and these tissues must be denatured to an extent where there will no longer be any danger of spreading disease.

In Federally inspected packing plants, the U. S. Bureau of Animal Industry's Meat Inspection Division exercises strict control of these operations. Diseased product is marked U. S. Condemned, and considerable progress has been made in recent years in improved handling of condemned product. Diseased parts can be discharged from inspection tables into hashing and washing equipment, and then blown directly into rendering equipment where the material will be sterilized.

The livestock and meat industry suffers tremendous losses because of these conditions, and steps are being taken to correct this problem at its source. It is

realized that this is not to be accomplished through improved equipment alone. The economic aspects of the problem are nearly overwhelming in magnitude and, added to this are the equally important health considerations.

In this connection it is pointed out that veterinarians throughout the country are waging unrelenting war against the ravages of disease and parasites on our livestock population.

Those who are engaged in this work, which includes all segments of the livestock and meat industry, need the support, counsel, and co-operation of your organization.

One word of caution in this connection—regimentation is not a successful method of getting results. There must of course, be rules and regulations to be enforced by agencies having police powers, but their actions must be predicated upon sound judgment, facts, and fairness to all concerned. Unnecessary or unimportant requirements should not be "shoved down the throat" of any industry merely because they "sound good" from a theoretical standpoint. There are too many vitally important problems facing us at the present moment to waste time, effort, or money, on fancy gadgets or unnecessary frills. The combined resources of all groups concerned with sanitary control should be focused on the basic problems of our food producing industry. Sanitation ranks first among these problems. Progress has been made toward this end. We are now finding more and more tools and methods that are available for use. Improved equipment design is certainly one of these.

The use of DDT as an insecticide, and antu for rodent control, and many of the new and improved detergents should receive mention as progress.

Additional research, education, co-operation, and teamwork must not be neglected.

CHEMICAL AGENTS GIVE QUALITY IMPROVEMENTS IN FISHERIES[1]

CECIL G. DUNN
Department of Food Technology
Massachusetts Institute of Technology, Cambridge

(REVIEW PAPER)

The desirability of using chemical agents for sanitizing equipment and facilities in fishery plants is explained. The value of using germicidal ice and antioxidants also is shown. Mixtures of chemical compounds sometimes have advantages over single compounds. Selected compounds and mixtures are suggested. Chemical agents used in treating fish or fish products must be nontoxic.

The quality of fish and fish products, like other foods, depends upon such factors as nutritive value, palatability, flavor, odor, and general appearance. It is at its best, as far as the fisherman and consumer are concerned, at the time the fish is removed from the water. Nothing can be done to improve the original quality of the product, but much may be done to retain it.

Loss of quality in fish and fish products is associated primarily with bacterial, enzymatic, and oxidative deterioration. To prevent loss of quality, two general procedures are available. The first of these is concerned with the prevention of the contamination of the product with microorganisms from the environment and entails the application of the principles of sanitation. Emphasis is on the equipment or facilities with which the fish or its products come into contact. Control of this environment, in connection with our problem, involves the use of detergents or cleansing agents to rid the surfaces of the contaminating soil and of a large proportion of the spoilage organisms, and the use of bacteriostatic or germicidal agents, sometimes referred to as sanitizing agents, to inhibit or destroy bacteria and other microorganisms.

The second general procedure available for maintaining the original quality of the product is concerned with the prevention or retardation of spoilage caused by microbes resident on or in the product, by enzymes, and by rancidity. In this procedure, action is directed towards the fish, or its product, and involves the employment of preservatives and antioxidants usually with only small modifications of the customary methods of preservation, such as icing, salting, drying, and freezing.

The selection of a chemical agent for use as a detergent, sanitizer, preservative, or antioxidant should be made only after the favorable results of extensive research substantiate such choice. Although many chemical substances, inorganic and organic, have been investigated, the number of suitable agents available is limited, because of failure to meet certain basic qualifications. The chemical agent used in connection with the handling or processing of fish should satisfy most, if not all, of the following requirements. It must (1) be relatively nontoxic; (2) not impart objectionable odors, flavors, texture or color to the product, nor cause bleaching of the natural fish pigments; (3) not impair nutritive value; (4) not accelerate rancidity of constituent oils; (5) be effective for the purpose for which chosen and under the conditions of use; (6) be relatively non-corrosive; (7) be authorized for use under existing governmental laws and regulations. Obviously, it is not a simple matter to find a chemical agent which will satisfy all of the foregoing requirements.

[1] Presented before the Seventh Annual Food Conference, Boston, Mass., June 4, 1947.

PREVENTION OF CONTAMINATION

Contact of fish and fish products with unclean or contaminated surfaces or equipment hastens spoilage due to microorganisms. Thus, the first important action in the retention of quality is concerned with the proper control of the environment with which the fish comes into contact. Involved are the decks and holds of the fishing boats, storage bins, conveyors, filleting tables, knives, processing equipment, and other facilities.

There are two important steps in the cleaning operations: (1) the removal of the soil, which may include slime, blood, proteins, fats, and other organic or inorganic matter, and (2) the destruction or inhibition of the bacteria and other microorganisms resident on the surfaces by sanitizing.

Removal of Soil. The use of relatively large amounts of clean, potable water is the basis of the cleaning operation. However, water by itself is not usually an effective agent for soil removal. Accordingly, special cleaning materials, commonly known as detergents, are used in conjunction with it. The purposes of the detergents are to wet the surface being cleaned, emulsify fats, dissolve food substances, break up (deflocculate) particles of dirt, disperse the products of the chemical reactions in order to prevent precipitation and film formation, and facilitate rinsing. The detergent may also act as a water softener and germicide *(11)*. (Refer to Table 1.)

TABLE 1

Properties of Some Detergents

Detergent	Wetting Action	Emulsifying Action (on fats)	Dissolving Action (proteins, etc.)	Breaking up action (deflocculation)	Dispersing Action	Rinsing Action	Water Softening Action	Germicidal Action [b]	Corrosion prevention Action
Sodium hydroxide (Caustic soda, lye)	P[a]	P	G	G	P	P	P	E(1)	
Sodium carbonate (Soda ash)	P	P	F-G	P	P	P	G	(4)	
Trisodium orthophosphate (TSP)	P	S	G	S	P	G	G	G(3)	
Sodium hexametaphosphate (Calgon)			G		E	E	G		
Sodium tetraphosphate (Quadrafos)			G		E	E	G		
Tetrasodium pyrophosphate (TSPP, or Pyro)			G		E	E	G		
Sodium metasilicate	F	S	G	E	P	G	P	G(2)	G
Soaps	G	G		G		P			

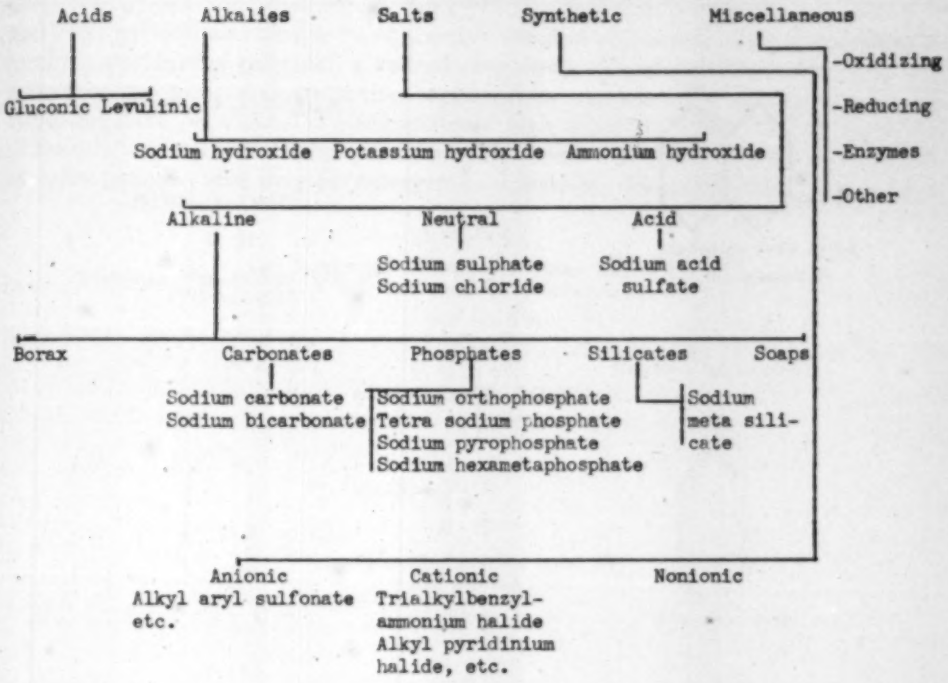
[a] Code: E = excellent; G = good; S = satisfactory; F = fair; P = poor, or lacking.

[b] Alkaline detergents rated on a relative basis, number (1) ($NaOH$) being best, number (2) (Na_2SiO_3) being second best, etc.

Detergents may include the alkaline salts, soaps, and "soapless" soaps or synthetic detergents *(11, 20, 22, 57)*. (Refer to Table 2.) The best detergents are usually mixtures of several chemical agents, such as, for example, one containing sodium hydroxide, trisodium phosphate, sodium metasilicate, and sodium hexametaphosphate ($Na_6P_6O_{18}$) (Calgon), or sodium tetraphosphate ($Na_6P_4O_{13}$) (Quadrafos). The composition of the mixture employed will depend upon the

TABLE 2

A Classification of Some Detergents



purpose for which designed. Soaps are best when used in soft water, are excellent wetting agents, but possess limited properties of emulsification and deflocculation. Synthetic detergents possess good wetting and detergent properties and are not usually adversely affected by water hardness, moderate acid or alkaline solutions, salts, or oxidizing and reducing agents. This class of detergents, however, is not without limitations, which must be known and understood before use. It includes such agents as the alkyl sulphates, alkyl aryl sulphates and the quaternary ammonium, phosphonium, and sulphonium compounds.* (Refer to Table 3.)

Thoroughness is the key to success in cleaning. This involves, in addition to the use of water (preferably hot) and detergents, the application of "elbow grease" and intelligence. Usually 90 per cent, or more, of the microorganisms are removed by an efficient cleansing operation.

Sanitizing. After the removal of the soil from the surfaces, sanitizing agents should be employed to destroy or inhibit the development of the remaining organisms. Oxidizing agents, such as hypochlorites and chloramines; quaternary ammonium compounds; miscellaneous other chemical compounds; and hot water and steam, when available, may be used as sanitizing agents. On shipboard, the use of chemical sanitizers is indicated. (Refer to Table 4.)

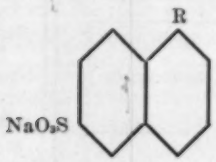
The chlorine-liberating compounds, such as calcium hypochlorites (chlorinated lime, Perchloron, HTH, B-K, etc.) and the sodium hypochlorites (Diversol, etc.) are generally used in concentrations such that the available chlorine in the solutions employed for sanitizing contain 100 to 200 parts per million, or a residual of 50 p.p.m.

* These are marketed under such trade names as the *Nacconols, Duponals, Gardinols, Roccal, Rodalon, Emulsept, Cetab, Triton* X-400, etc.

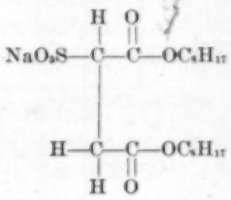
TABLE 3

The Structure of Some Synthetic Organic Detergents

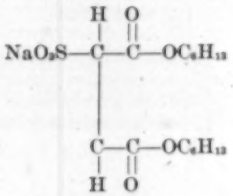
1. ANIONIC:



Alkyl aryl sulfonate
(Aerosol OS)

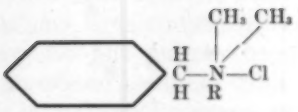


Di octyl sodium sulfosuccinate
(Aerosol OT)

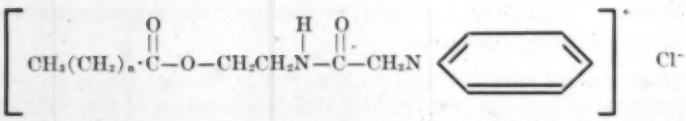


Di hexyl sodium sulfosuccinate
(Aerosol MA)

2. CATIONIC:



Alkyldimethylbenzyl ammonium chloride
(Roccal)
(Rodalon)
(Onyx BTC)



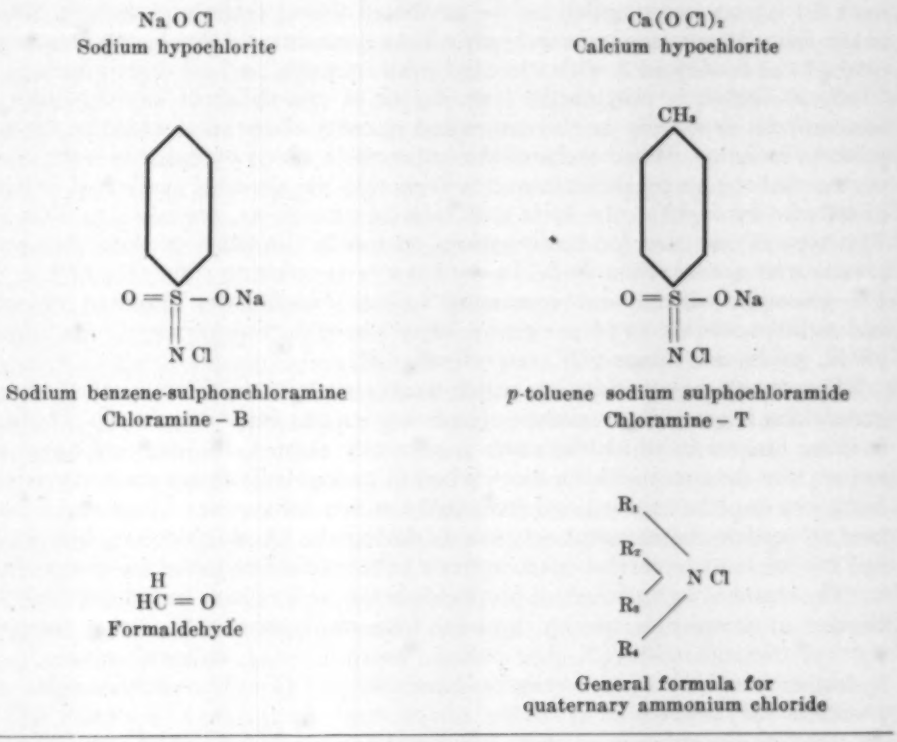
N (higher acyl esters of colamino formylmethyl) pyridinium chloride.
(Emulsept)

after use. Such agents are most effective in acid solution, but should not be used for the treatment of equipment or facilities where such use may cause excessive corrosion. Chloramines, such as chloramine T (refer to paper by Sotier and Conklin), are, in general, more stable but slower acting than hypochlorites and may offer advantages under special conditions. For further details concerning this class of germicides, refer to the publications by McCulloch *(22)*, Charlton and Levine *(7)*, Scales *(29)*, and others *(20)*.

The quaternary ammonium salts have shown considerable promise as germicidal and bacteriostatic agents, as well as detergents. Among these may be mentioned alkyldimethylbenzylammonium chlorides [a] *(10)*, cetyltrimethylammonium bromide [b], and cetyl pyridinium chloride [c] *(28)*, and N (higher acyl esters of colamino formylmethyl) pyridinium chloride[d], a related compound. These cationic compounds are relatively non-toxic and are active bactericidally against both Gram-positive and Gram-negative organisms in comparatively high dilution. However, the presence of lecithin, cephalin, and other phospholipids protects organisms against the action of both cationic and anionic detergents. Likewise, the germicidal action of a

TABLE 4

The Names and Formulas of Some Sanitizers



cationic compound may be blocked by the presence of an anionic detergent. In general, cationic detergents are most active as inhibitory agents on the alkaline side of neutrality (but there are exceptions), whereas the anionic detergents are most active bacteriostatically on the acid side of neutrality *(22)*.

The alkyl aryl sulphonates*, anionic compounds, have shown promise also.

Formaldehyde (9 parts HCHO per thousand of solution), containing 0.5 part per thousand of sodium nitrite, is an effective germicide for use as a spray on sur-

[a] Marketed as *Zephiran, Roccal, Rodalon*, etc.
[b] Marketed as *Cetavlon, CTAB*, etc.
[c] Marketed as *Ceepryn, etc.*
[d] Distributed as Emulsept (E607-special)
* Marketed as Aerosol OS, Nacconol NR, etc.

faces with which fish or fish products may come into contact, according to Tarr *(41)*. Formaldehyde alone is a good germicide, but it is corrosive to iron surfaces. Sodium nitrite reduces its corrosive action without lowering its effectiveness. Before spraying the surfaces with formaldehyde, they must be cleaned to remove organic matter.

Although sodium nitrite reduces the corrosive action of sodium hypochlorite, it also destroys its germicidal activity.

Prevention and Retardation of Deterioration Due to Microorganisms and Enzymes. Numerous efforts, some of them successful and many otherwise, have been made to preserve fish and fish products by chemical means. These have involved the use of germicidal ices, brines, dips, gases, antioxidants, and other means.

The use of chemical preservatives, including germicidal ices, is based on the fact that the spoilage of fish is largely due to bacteria and begins on the surface. Wood, Sigurdsson and Dyer (1942) stated that the "major changes rendering fish unfit for human consumption can be attributed almost entirely to surface pollution of the fish with spoilage bacteria" *(56)*. They demonstrated this by the contact plate method and confirmed it with trimethylamine, tyrosine and pH determinations.

Germicidal Ices. Germicidal ices may be of two different kinds, eutectic and non-eutectic, depending on the nature and quantity of chemical added to the water prior to freezing. When a chemical compound is added to water in such concentration that the ice prepared from it will contain the chemical compound uniformly distributed throughout, the ice is known as an eutectic ice, according to Tarr *(48)*. This type of ice, used for investigations on fish in Germany, accomplishes greater preservative action primarily because it has a lower melting point than ordinary ice. For example, eutectic ices containing sodium bicarbonate, disodium phosphate, and sodium chloride (23.6 per cent solution) have melting points of approximately 28°F., 30°F., and minus 6°F., respectively *(48)*.

The common germicidal ice, which usually contains only low concentrations of germicides, is generally a mixture of ordinary ice and eutectic ice *(48)*. During the freezing process in which the water is generally aerated, the chemical agent tends to pass into the core of the ice block where it undoubtedly forms a eutectic mixture. Such ices must be crushed and thoroughly mixed before use. Unaerated mixtures tend to occlude the chemical compounds during the freezing process, but crushing and mixing must be carried out to insure a uniform distribution of the germicide.

The chemical agents used, or proposed for use, in ices have included a fairly large number of compounds, among them the following: chlorine-liberating compounds *(4, 15)*, benzoic acid *(48, 49)*, sodium benzoate *(15)*, colloidal silver *(1, 48)*, hydrogen peroxide *(48)*, ozone, sodium nitrite *(53, 55)*, sulphonamides *(48)*, penicillin *(48)* and others *(1, 48)*.

Chlorine-liberating compounds alone and combined with other germicides, have been employed in manufacturing germicidal ices. Chen and Fellers *(8)* reported that ice containing 0.02 per cent available chlorine was an effective preservative for fish. Frandsen *(15)* patented an antiseptic ice containing chloramine T and sodium benzoate. The mixture of these chemicals is added to water in the proportion of 12 to 48 ounces per ton before freezing. It is claimed that the ice has properties which are superior to ordinary ice for the preservation of fish and other foods.

Benzoic acid *(48, 49)* and benzoates *(15)* have been advocated for use in preparing germicidal ices. Tarr and Bailey *(49)* found that there was only slight improvement in the keeping qualities of dressed halibut and black cod when stored in crushed ice which contained 0.1 per cent benzoic acid. Tarr and Sunderland *(50)* demonstrated that benzoic acid, benzoates and *p*-hydroxybenzoic ethyl ester suppressed the formation of trimethylamine in fish muscle undergoing spoilage without

significantly affecting the numbers of bacteria. Inasmuch as the amount of trimethylamine is sometimes used as an index of the quality of fish, the use of benzoic acid might lead to erroneous conclusions.

Tarr and Sunderland *(53)* pointed out that ice containing 0.1 to 0.5 per cent sodium nitrite was a much better preservative of fish than ordinary ice and was more efficient than ice containing benzoic acid. They found that bacterial spoilage of dressed halibut, pink salmon, and black cod was markedly inhibited by the use of crushed ice that contained 0.1 to 0.5 per cent of sodium nitrite. They based their conclusions on the results of bacteriological examinations and organoleptic tests. The halibut so treated turned yellow on its white ventral surface. A combination of sodium acid phosphate with sodium nitrite in ice did not enhance the keeping qualities of dressed chum salmon over ice containing only sodium nitrite, according to Tarr and Sunderland *(55)*. Sodium acid phosphate did not appreciably affect the pH of the fish muscle.

Tarr *(48)* has investigated the use of a number of modern antiseptics as constituents of germicidal ices. He has drawn several conclusions from his researches, among which are the following. A slightly acid rather than a neutral or slightly alkaline solution favors the action of many germicides. A commercially manufactured ice containing 0.05 per cent of a mixture of chloramine T and sodium benzoate resulted in only a slight improvement in the keeping quality of lemon sole. Ices containing 0.067 per cent of chloramine B or chloramine T retarded the rate of bacterial spoilage but slightly. However, an ice containing a mixture of 0.067 per cent of chloramine B and the same concentration of sodium benzoate was somewhat more effective than chloramine B alone. There was no noticeable improvement in the keeping quality of lemon sole due to the incorporation in ice of 0.0176 per cent of alkyldimethylbenzylammonium chloride or 0.02 per cent of calamino formyl methyl pyridinium chloride. Bacterial spoilage of the scaly-fin flounder and of dressed lingcod was not delayed by ices containing 0.00067 per cent of 2-ethoxy-6, 9-diaminoacridine lactate, nor that of the starry flounder by ice containing 100 international units of penicillin per pound of ice. Ices containing 0.01 and 0.02 per cent of sulphanilamide, 0.01 per cent of sulphathiazole, and 0.076 and 0.1 per cent of sodium nitrite were generally more effective in delaying bacterial spoilage than any of the other chemical agents used.

Dips. The use of preservative dips for fish and fish products is not new. Several European countries, particularly Germany and the Scandinavian countries, have for a long time made use of chemical agents to preserve fish, occasionally using chemical compounds such as boric acid *(3)*, which are not permitted in the United States.

The literature contains references to the uses of a number of different compounds in an effort to preserve round fish and fillets. These include benzoic acid, sodium benzoate *(9, 14)*, boric acid, sodium hypochloride, potassium nitrate *(39)*, sodium nitrate *(39)*, sodium nitrite *(38, 39)*, formaldehyde or formalin, and other compounds.

Efforts to preserve round dressed fish have usually resulted in only a small degree of success, or in failure, undoubtedly due to the ineffectiveness of chemical agents in preventing bacterial action in the deep portions of the muscle, cut during dressing, or by scraping or forking.

Of the agents with promise which have been investigated during recent years may be listed benzoic acid, sodium benzoate, and sodium nitrite.

Mixtures of benzoic and boric acids (or their sodium salts) have been used to prevent the spoilage and reddening of salted cod fish and to preserve anchovies, caviar, crabs, fish roe, spiced herring, and other marine fish or fish products, particularly in Germany.

Fellers and Harvey *(14)*, recommended the use of sodium and magnesium benzoates and benzoic acid-benzoate mixtures for treating fillets and possibly round fish to prolong their keeping qualities. They pointed out that these agents were most effective at a pH range 4 to 4.5 and that concentrations of 0.15 to 0.5 per cent (with perhaps 0.3 as an optimum) of the benzoates should be used in the dipping solutions. A two-minute dip was found to be satisfactory. The storage life of treated fillets of cod, haddock, and red perch was several days longer than that of untreated controls. Only a small amount of benzoate was retained by the fillets after dipping—about 0.01 per cent after a 2-minute dip in a brine containing 0.3 per cent sodium benzoate.

Tarr and Sunderland *(50)* observed that the keeping quality of fillets (which were subsequently smoked) was slightly improved by brief immersion in 20 per cent brines which contained benzoic acid. This favorable effect was not improved by the addition of other acidic substances. In 1939, they *(51)* expressed the thought that the use of sodium benzoate might be nearly as effective as that of benzoic acid when employed in the same concentration, since the acid is neutralized by contact with the fish muscle. They have also shown that freshly-shucked clams were improved in respect to their keeping qualities by storing them in a dilute sodium benzoate brine. Such treatment did not alter the palatability or flavor of the clams.

The role of sodium benzoate and other agents in the preservation of fresh shucked clams was investigated by Piskur and Stansby *(26)* in 1946. They found that clams stored in 0.1 per cent benzoate in a 3.5 per cent brine had a satisfactory storage life of 12 to 13 days when packaged in glass containers which were packed in crushed ice. Dipping of the clams in a benzoate-salt mixture followed by storage in citrate or phosphate buffer solution at a pH of 5.2 to 5.3 in glass containers surrounded by crushed ice appeared to be the best treatment. Such clams had a keeping time of 14 to 15 days and could be shipped from Southeastern Alaska to markets in the Pacific Northwest. The use of sodium benzoate in the dipping and storage solutions did not alter the flavor or palatability of the freshly shucked clams. No advantage was obtained by dipping the shucked clams in solutions of hypochlorite or Nipicide before storage.

Fish may be preserved during shipment by the use of a bactericide known as "Hyperol" according to reports from Hungary. Hyperol (or perhydrate) is an odorless and colorless combination of urea and hydrogen peroxide, which contains 35 per cent hydrogen peroxide.

ANTIOXIDANTS

Problems have arisen in connection with the storage of certain fish which contain large amounts of fat, such as the herring, mackerel, mullet, pilchard, and salmon, on account of their susceptibility to an oxidative type of deterioration during storage, known as rancidity, which develops rapidly at 70°F. or higher. The fats are composed of a relatively large proportion of unsaturated fatty acids *(5)*. The unsaturated bonds of these acids become oxidized to peroxides and undesirable odors and flavors are formed. In addition, objectionable visible changes may occur, such as the appearance of rust, and, in the case of salmon, the bleaching of the red pigments.

Inception of rancidity is accelerated by lipoxidases; by certain metals, such as copper and iron; by ultra violet radiation; by ozone; and by other agents. The action of lipoxidase, which is found in the flesh of the herring, is in turn catalyzed by sodium chloride and may take place at temperatures as low as minus 4°F.

In our present discussion, we are interested primarily in chemical antioxidants. In the research carried out to determine the effect of various chemical agents in preventing the oxidative rancidity referred to above, resort has been made to the

treatment of fish with dips containing the antioxidant in aqueous solution or in brines; with coatings containing an edible oil, an antioxidant, and occasionally an antiseptic; with glazes containing the antioxidant; and with gases.

It will be obvious that the antioxidant used in connection with aqueous solutions and brines should be soluble in water (the vehicle) as well as in oil. Tarr was interested particularly in this type of antioxidant and has carried out a considerable amount of research in this connection. Tarr *(43, 47)* has investigated the value of a number of antioxidants, including sodium, ethyl, and propyl gallates, ascorbic acid, cysteine, thiourea, and lauryl thiodipropionate on filleted and minced fish. The fillets were dipped for one minute in an aqueous solution of the antioxidant, drained, wrapped in cellophane and stored at the desired temperatures. The minced fish (fillets) was thoroughly mixed (by means of an electrical mixer) with the required amount of the antioxidant in aqueous solution. One-ounce portions of the treated minced product were placed in six-ounce glass jars equipped with screw caps and stored at the desired temperatures.

As a result of these researches, Tarr formulated certain conclusions. Both ethyl and sodium gallates retarded oxidative rancidity in fillets of unfrozen white spring salmon (dipped in sodium chloride solution) over short periods of time, but ethyl gallate was a much better antioxidant to use on fish intended for long storage. Dipping of fillets of pink salmon for one minute in 0.05 per cent solutions of ethyl or propyl gallates considerably delayed the appearance of rancidity at 14°F. Ethyl gallate, propyl gallate and ascorbic acid, each in 0.05 per cent concentration, considerably retarded rancidity in minced red spring salmon and herring flesh stored at 4°F. However, under similar conditions, cysteine afforded only slight protection and lauryl thiodipropionate and thiourea either gave no protection or actually accelerated the oxidation of the unsaturated fatty acids. Both ethyl and propyl gallates, in concentrations of 0.02 per cent, considerably delayed the development of rancidity in minced red spring salmon and soho salmon, particularly at temperatures of minus 4°F. and minus 18°F.

Tarr observed that the development of rancidity in minced red spring salmon, stored at 14°F., was stimulated by one per cent sodium chloride. However, the simultaneous presence of 0.02 per cent of ethyl gallate strongly retarded this reaction. The red color of salmon fillets treated with ethyl gallate did not fade after prolonged storage at temperatures considered to be rather unfavorable, whereas untreated salmon flesh bleached quite rapidly under similar conditions.

Silver *(31)* has reported on the use of special coatings containing an antioxidant and a benzoate preservative. On the basis of preliminary tests, superior keeping qualities have been demonstrated by treated fish when stored between 40 and 75°F. The technique was as follows: A mixture (one containing 50 per cent of magnesium benzoate and 50 per cent of benzoic acid was best) was prepared which contained 4.5 pounds of benzoate-type preservative per 1,000 pounds of salt. This mixture was applied to fish at the rate of 30 pounds per 100 pounds of fish. Thus, the concentration of benzoates was approximately 0.1 per cent based on the weight of the salt plus the fish. The salted fish was coated with a film of edible oil, for example, partially hydrogenated cottonseed oil, which contained 0.2 per cent by weight of dihydroguaiaretic acid (N. D. G. A.) or other equally effective antioxidant. It has been estimated that the cost of this treatment should not exceed two cents per pound of final product. Such a process, with suitable modification, may be used in connection with frozen, smoked, dried, dry-salted, or brined fish.

Mullet (southern coast) coated with coconut oil containing N. D. G. A. and 0.1 per cent ethyl vanillate and then packed in brine containing 0.10 per cent ethyl

vanillate was stored at 90°F. along with controls by Pearl and McCoy (1945) *(25)*. At the end of three months, the peroxide values, used as indices of the relative rancidities of the oils, were 2.5 for the pack containing ethyl vanillate and 250 for the control packed in brine alone. The pack containing ethyl vanillate was in a "remarkable state of preservation" after eight months, whereas the controls and other packs were in advanced stages of decomposition. In further experiments, 0.10 per cent of isobutyl vanillate was found to be very effective at room temperature as a preservative for pickled herring.

Tarr *(47)* has investigated the effect of glazing and of dipping with antioxidants on the development of rancidity in salmon fillets and steaks. The following conclusions may be drawn from his report. Glazing retarded fat oxidation considerably. Glazes made from solutions containing 0.5 per cent ascorbic acid and 0.5 per cent sodium ascorbate at pH 6 prevented measurable development of rancidity in red spring salmon steaks over a period of 84 days at 14°F. A glaze containing ethyl gallate was not superior to one of distilled water for red spring and coho salmon steaks stored at 14°F.

Possible disadvantages of glazing individual steaks or fillets, from the customer's point of view, according to Tarr, were increased weight, free liquid in the package after thawing, and the tendency for the chemical to sink into the flesh after thawing, reducing the pleasantness of cooking.

Dipping of fillets of red spring salmon for 5 minutes in 0.25 to 1.0 per cent solution of ascorbic acid or of sodium ascorbate at pH 6 strongly retarded the development of rancidity over a period of 122 days at 14°F. A minimum of 0.04 per cent of ascorbic acid was required in fish flesh in order to prevent the development of rancidity to an important extent. Dipping fillets of red spring salmon for 5 minutes in 1 per cent ascorbic acid resulted in a concentration of 0.043 per cent of the acid in the fish flesh.

Research is being carried out on the use of antioxidants at the Fishery Technological Laboratory at Seattle, Washington *(2)*. Tentative conclusions have been reached concerning the effects of antioxidants in preventing rancidity in fillets of pink salmon stored at 3°F. for three months. No treatment with antioxidants has proven entirely successful in "preventing incipient rancidity in the fatty surface flesh." Those fillets which were treated with N. D. G. A. in water or in cottonseed oil possessed no off-odor and were slightly preferable to untreated samples. The action of N. D. G. A. was not noticeably improved by ascorbic, benzoic or citric acids, but the acids caused off-odors.

Hydroquinone has been used in concentrations up to 0.5 per cent in experimental trials in Germany to prevent rancidity in salt herrings. It was the most effective antioxidant used.

According to Tarr, preliminary tests have indicated that the onset of rancidity in the flesh of fatty fish may be "almost entirely prevented" by storage in the frozen state in an atmosphere of carbon dioxide or nitrogen gas.

The development of rancidity in fatty fish is greatly delayed by storage in a high vacuum.

The use of gases to prevent rancidity in individual packages presents certain obstacles. Containers must be gas tight, for the presence of even very small amounts of oxygen may lead to fat oxidation. Gases used for storage—carbon dioxide and nitrogen—must likewise be free of oxygen.

Fish Oil Antioxidants. Bucher *(6)* of the Seattle Fishery Technological Laboratory has reported on the use of a number of antioxidants for fish oils. She employed an accelerated oxidation test wherein air was bubbled through the oils at 212°F.

Induction periods, which varied from 0.5 to 41.5 hours for different fish oils, in the presence of and in the absence of the antioxidants were measured. Antioxidants were compared on the basis of their protection factors (the ratio of the induction period in the presence of the antioxidant to the induction period in the absence of the antioxidant). Seed extracts, such as wheat germ oil, gave little protection except at concentrations which were too high for commercial utilization. Gum guaiac, citric acid, and tartaric acid were ineffective. Hydroquinone was effective but imparted an off-flavor. Nordihydroguaiaretic acid protected salmon oil, which has a short induction period, but a greater concentration was necessary than for lard. Concentrations of N. D. G. A. greater than 0.1 per cent produced a slightly bitter taste. Gallic acid and some of its esters in 0.1 per cent concentration had protective factors ranging from 2.5 to 20, depending on the type of fish oil.

CONCLUSIONS

1. Chemical detergents are essential for efficient cleaning operations in the fishery industry. Mixtures of detergents, particularly of the alkaline ones, usually produce better results than single compounds. The use of synthetic organic detergents may be advantageous under certain conditions. Experimentation with various products should demonstrate which are best for a given purpose.

2. The cleaned surfaces of the equipment and facilities should be treated with sanitizing agents to destroy or inhibit the development of microorganisms not removed during the cleaning process. Hypochlorites, chloramines, quaternary ammonium compounds, formaldehyde containing sodium nitrite, and other agents have given good results. All sanitizers have limitations, which must be understood in order that they may be used intelligently.

3. A variety of chemical compounds have been used in the preparation of germicidal ices. The most promising of these have contained sodium nitrite, sulphanilamide, or sulphathiazole.

4. Benzoated brines have extended the storage life of fillets and freshly shucked clams.

5. Antioxidants, particularly nordihydroguaiaretic acid, ethyl gallate, ascorbic acid, and sodium ascorbate at pH 6, have produced good results in retarding the development of rancidity in the flesh of fatty fish.

6. Nordihydroguaiaretic acid, gallic acid and some of its esters, in concentrations of 0.1 per cent or less, have been used successfully to protect fish oils from rancidity.

7. No chemical agent should be used in the treatment of fish or fish products which is toxic or which has not received the approval of the appropriate governmental authorities.

REFERENCES

1. Anon. Certain aspects of the German fishing industry, *Fishery Leaflet 211, Fish and Wildlife Service*, U. S. Dept. Int., December 1946.
2. Anon. Technological research in service laboratories, December 1946, *Commercial Fisheries Rev.*, *9* (No. 2) 20 (1947).
3. Berube, L. Modern practice in fish preservation by cold, *Food Res.*, *3*, 69-74 (1938).
4. Bridston, M. E. Antiseptic ice reduces spoilage, *Food Ind.*, *13* (No. 4) 43 (1943).
5. Brocklesby, H. N. The chemistry and technology of marine animal oils, Bulletin No. LIX, *Fish. Res. Bd. Can.* (1941).
6. Bucher, D. L. Antioxidants for fish oils, *Fishery Market News*, *7* (No. 7) 17-19 (1945).
7. Charlton, D., and Levine, M. Germicidal properties of chlorine compounds, *Iowa Eng. Exp. Sta., Bull.* 132, March, 1937.
8. Chen, Tung Pai and Fellers, C. R. Fish preservation by hypochlorites, *Univ. Washington Publication in Fisheries*, *1*, 205-227 (1926).

9. Crowther, H. R. Benzoate coated wrappers for fish fillets, *Quick Frozen Foods, 3,* 13-15, 24-34 (1940).
10. Dunn, C. G. Antiseptic and germicidal properties of a mixture of high molecular alkyl-dimethyl-benzyl-ammonium chlorides, *Amer. Jour. Hyg., 26* (No. 1) 46-52 (1937).
11. Dunn, C. G. Sanitation of cold storage plants, Outline presented at North Atlantic Regional Training Conference for Refrigerated Warehouse Personnel, Hotel Hershey, Hershey, Pa., August 18-21 (1946).
12. Dyer, W. J., Sigurdsson, G. J., and Wood, A. J. A rapid test for detection of spoilage in seafish, *Food Res., 9,* 183-187 (1944).
13. Elliott, R. Evaluation of surface pH as a freshness index for fish fillets, *Food Res. 12,* 87-98 (1947).
14. Fellers, C. R., and Harvey, E. W. Effect of benzoated brine dips on keeping quality of fish fillets, *Food Res., 5,* 1-12 (1940).
15. Frandsen, L. Antiseptic ice, U. S. Pat. 2,398,781, April 23 (1946).
16. Galtsoff, P. S. Reaction of oysters to chlorination, Research Report 11, Fish and Wildlife Service, U. S. Department of the Interior, Washington (1946).
17. Goetz, A. S-coating—A self sterilizing surface for packaging materials, *Modern Packaging, 18* (No. 1) 113-115 (Sept. 1944).
18. Hess, E. Instructions for sterilizing fish plants, etc., *Fish. Res. Bd. Can., Progress Reports, Atlantic Sta.,* No. 27, 3-5 (1940).
19. Hess, E., and Gibbons, N. E. Studies on salt fish, X. Effect of disinfectants and preservatives on red halophilic bacteria, *Jour. Fish. Res. Bd. Can., 6* (No. 1) 17-23 (1942).
20. Jacob, M. B. The Chemistry and Technology of Food and Food Products, Chapter VI, *Interscience Publishers,* Inc., New York, 1944.
21. Lucke, F. Fischindustrielle Taschenbuch, Praxis und Wissenschaft der Seefischverarbeitung (3 Auflage), Serger und Hempel, Braunschweig, 1940.
22. McCulloch, E. C. Disinfection and Sterilization, 2nd Ed., Lea & Febiger, Philadelphia, 1945.
23. Mueller, W. S., Bennett, E., and Fuller, J. E. New sterilizing agents for dairy use, *Bull. No.* 436, p. 30, Mass. State College, Sept., 1946.
24. Neidig, C. P., and Burrell, H. The esters of para-hydroxy-benzoic acid as preservatives, *Drug and Cosmetic Industry, 54,* 408, 481 (1944).
25. Pearl, I. A., and McCoy, J. F. Vanillic acid esters as food preservatives, *Food Ind., 17* (No. 12) 1458-1461, 1600, 1602, 1603, 1604 (1945).
26. Piskur, F., and Stansby, M. E. Preservation of shucked Alaska clams, *Commercial Fisheries Review, 8* (No. 4) 5-12 (1946).
27. Puncochar, J. F., Baldwin, W. H., and Pottinger, S. R. Studies on the "pink" discoloration of commercially shucked oysters, *Fishery Market News, 3* (No. 5) 6-10 (May, 1941).
28. Quisno, R., and Foter, M. J. Cetyl pyridinium chloride, *Jour. Bact., 52* (No. 1) 111-117 (1946).
29. Scales, F. M. The fundamental principles of chlorine sterilization and a new positive germicide, Paper presented before Laboratory Section of the 31st Annual Convention, *International Association Milk Dealers,* Oct. 17, 1938.
30. Scales, F. M., and Kemp, M. A new group of sterilizing agents for the food industries and a treatment for chronic mastitis, *Bulletin of Int. Assoc. Milk Dealers,* No. 19, 491-520 (April 14, 1941).
31. Silver, R. E. How to retard rancidity in salt-cured fish, *Food Ind., 17* (No. 12) 1454-1456, 1596, 1598, 1600 (1945).
32. Simon, P. N. Benzoate ice in fish preservation, Master's thesis, Massachusetts State College (1938).
33. Stansby, M. E. Judging the quality and freshness of fish by organoleptic methods, *Fishery Market News, 5* (No. 8) 3-7 (1943).
34. Stansby, M. E. Judging the quality and freshness of fish by organoleptic methods, I.S.D.I., Fish and Wildlife Service, *Fishery Leaflet* No. 94 (1944).
35. Stansby, M. E., and Griffiths, F. P. Carbon dioxide in handling fresh fish, *Ind. Eng. Chem.,* (Ind. Ed.) *27,* 1452-1458 (1935).
36. Tarr, H. L. A. The action of nitrites on bacteria, *Jour. Fish. Res. Bd. Can., 5* (No. 3) 265-275 (1940).
37. Tarr, H. L. A. Use of chemicals and ultraviolet light in preserving fish, *Proc. Inst. Food Tech.,* 145-148 (1940).
38. Tarr, H. L. A. The action of nitrites on bacteria: further experiments, *Jour. Fish. Res. Bd. Can., 6* (No. 1) 74-89 (1942).

39. TARR, H. L. A. Action of nitrates and nitrites on bacteria, *Jour. Fish. Res. Bd. Can., 6* (No. 3) 233-242 (1943).
40. TARR, H. L. A. Chemical inhibition of growth of fish spoilage bacteria, *Jour. Fish. Res. Bd. Can., 6* (No. 3) 257-266 (1944).
41. TARR, H. L. A. Germicidal sprays and prevention of corrosion, *Fish. Res. Bd. Can., Progress Reports, Pac. Coast Sta.*, No. 59, 7-9 (June, 1944).
42. TARR, H. L. A. Germicidal sprays, *Fish. Res. Bd. Can., Progress Reports, Pac. Coast Sta.*, No. 62, 12-13 (March, 1945).
43. TARR, H. L. A. Antioxidants and prevention of rancidity in certain Pacific coast fish, *Nature 154*, 824 (Dec. 30, 1944).
44. TARR, H. L. A. Chemical antioxidants for retarding the development of rancidity and bacterial increase in stored fish, *Jour. Diet. Assoc.*, 71-76 (Dec., 1944).
45. TARR, H. L. A. Control of rancidity in stored fish, *Fish. Res. Bd. Can., Progress Reports, Pac. Coast Sta.*, No. 64, 57-61 (1945).
46. *Ibid.*, II, No. 66, 17-20 (March, 1946).
47. *Ibid.*, III, No. 68, 52-54 (Sept., 1946).
48. TARR, H. L. A. Germicidal Ices, *Fish. Res. Bd. Can., Progress Reports, Pac. Coast Sta.*, No. 67, 36-40 (1946).
49. TARR, H. L. A., AND BAILEY, B. E. Effectiveness of benzoic acid ice for fish preservation, *Jour. Fish. Res. Bd. Can., 4* (No. 5) 326-327 (1939).
50. TARR, H. L. A., AND SUNDERLAND, P. A. Preliminary note on the keeping quality of lightly smoked fish, *Progress Reports, Pac. Coast Sta.*, No. 37, 7-11 (1938).
51. TARR, H. L. A., AND SUNDERLAND, P. A. The role of preservatives in enhancing the keeping quality of fresh fillets, *Fish, Res. Bd. Can., Progress Reports, Pac. Coast Sta.*, No. 39, 13-16 (1939).
52. TARR, H. L. A., AND SUNDERLAND, P. A. Preservation in ice. Use of sodium nitrate, *Modern Refrig., 43* (No. 503) (1940).
53. TARR, H. L. A., AND SUNDERLAND, P. A. Effectiveness of ice containing sodium nitrite for fish preservation, *Jour. Fish. Res. Bd. Can., 5* (No. 1) 36-42 (1940).
54. TARR, H. L. A., AND SUNDERLAND, P. A. The comparative value of preservatives for fresh fillets, *Jour. Fish. Res. Bd. Can., 5* (No. 2) 148-163 (1940).
55. TARR, H. L. A., AND SUNDERLAND, P. A. Ices with sodium nitrite and sodium acid phosphate for fish preservation, *Jour. Fish. Res. Bd. Can., 5* (No. 3) 244-248 (1940).
56. WOOD, A. J., SIGURDSSON, G. J., AND DYER, W. J. The surface concept in measurement of fish spoilage, *Jour. Fish. Res. Bd. Can., 6* (No. 1) 53-62 (1942).
57. VAN ANTWERPEN, J. F. Surface-active agents, manufactured in America and commercially available, *Ind. Eng. Chem., 35*, 126 (1943).

THE FIELD EVALUATION OF ARMY NUTRITION [1]

ROBERT E. JOHNSON
*Harvard Fatigue Laboratory, Boston, Massachusetts**

That part of army nutrition to be discussed here is concerned with the effects of rations on the men who eat them. The information collected by many individual observers in theaters of combat, by a variety of survey teams, by those who have conducted field trials and by certain laboratories which have worked on problems of troop feeding all contributed in one way or another to an Army feeding program which by the end of the war was in general very successful. Our laboratory had little experience with and therefore is not competent to speak either about technological matters such as the Quartermaster Subsistence Laboratory in Chicago has handled or about studies on group feeding as conducted by the Nutrition Division of the Surgeon General's Office. Our single contribution to the subject at hand was to assist the offices of the Quartermaster General and Surgeon General in applying systematically a workable scheme for examining troops in the field in a variety of places including the Arctic, the desert, the Rocky Mountains and tropical areas in various parts of the Pacific.

Army nutrition poses some problems which are common to all programs of feeding groups of people, whether civilian or military, and in addition forces the consideration of other problems which are almost peculiarly its own. The general problems which have to be faced include supplying a balanced ration over a long period of time, and this involves all of the manifold complexities of procurement, supply, food preparation and inspection. Special problems are raised by the necessity to develop and procure rations far in advance of anticipated use, to ship them into any type of climate, to store them under any kind of condition for long periods of time without undue spoilage and, finally, to issue them in a form which men will eat. On the one hand, it is necessary to include in the rations a variety of nonperishable items and, on the other, these items must be capable of preparation in a reasonably palatable form. In our experience this question of acceptability has been among the most important in determining the adequacy of a ration for troops. As my friend, Lt. Colonel R. M. Kark, RCAMC, has said, "It is far better for troops to eat an unbalanced ration than not to eat a balanced one." Since the field rations, such as C and K, presented the most difficult problems to solve in this respect, and since most of our experience was not with garrison feeding but with feeding in the field, the rest of this discussion will be devoted to illustrations drawn from the field rations.

In judging the merits of a field ration and its adequacy for soldiers one has to take into account many factors, including its utility in situations for which it was designed, its packaging, its acceptance by soldiers, and its effects on the military efficiency, physical fitness, general health, morale and biochemical balance of those who have to eat it. There are satisfactory techniques which in the hands of trained and skilled observers will give reliable results in assessing these various factors even in combat. However, it is our opinion that no single observer can have the requisite knowledge to apply all of these techniques and that teams of observers are essential for accurate results. The utility of a ration in fulfilling the purpose for

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

* Present address, Medical Nutrition Laboratory (an installation under the jurisdiction of the Surgeon General, U. S. Army) 1848 West Pershing Road, Chicago 9, Illinois.

which it was designed can be judged by interviews with personnel in all echelons of command. Questionnaires are useful for this purpose but they can be very misleading unless filled out in the presence of an observer. Packaging is best judged by a competent quartermaster observer on the spot. Acceptance by soldiers can be judged by interviews, along with actual observation on wastage of the ration item by item. Military efficiency and morale are hardly susceptible of quantitative measurement, but interviews with the troops and the opinions of commissioned and noncommissioned officers in a unit will determine whether they are good or bad. It is clear that rations are only one of many influences on military efficiency and morale and the same is true of the effects of rations on general health. This can be judged by a competent medical officer, and it is highly important that he should be experienced enough to be cognizant of the fact that stresses of work, environment and disease sometimes produce conditions in soldiers that some professional nutritionists would attribute to poor rations. Biochemical balance can be measured with the aid of specially designed air-borne laboratories such as we have used in many places. I shall emphasize at the risk of repetition that no single type of observation is capable of answering the question whether a ration is adequate. There are too many different factors involved for a simple answer, and a balanced judgment is possible only by considering many different types of information.

Controlled experiments in laboratories and in the field have shown that certain foodstuffs are essential components of all field rations, and that certain others which in the long run are essential may be of little or no importance if periods of a week or two are in question. By studying the onset of serious physical deterioration among hard-working men most observers have agreed that water, salt, total calories from whatever source, and carbohydrates are indispensable for periods of even a day. Tough men can stand a lot but even the toughest will succumb very quickly if deprived completely of any of these at a time when he has to do hard physical work. Fig. 1 illustrates four experiments on the same well-conditioned soldier marching in our hot room under environmental conditions often found on a very hot day in many parts of the United States. He would march for 50 minutes at a standard army pace up a small grade, rest for 10 minutes, and then march again. When water was withheld his body temperature continued to rise to levels at which heat exhaustion was a very real danger. When he was allowed to drink whenever he was thirsty his body temperature stayed for 4 hours at a comfortable level. (It is not generally realized that "warming up" really does involve a rise in the body temperature to a level that would be considered "fever" by a nurse in a hospital. One is not comfortable doing work until he has "warmed up" to this extent.) Then his temperature began to go up because even though he was drinking as much as he wanted, he still was not taking in water as fast as he was losing it in his sweat and was beginning to suffer from dehydration. This failure of the thirst mechanism to keep up water balance during hard work may surprise some of you, but it is a point that has been well established in at least four laboratories and its cause has been satisfactorily established. Finally, when we made him drink water at the same rate as he lost it in the sweat, that is about a quart an hour, he remained comfortable, marched 18 miles easily, and ended with a low body temperature. Physical deterioration was almost completely prevented by ample intake of water. Similar experiments have shown that salt lost in sweat has to be replaced day by day to prevent deterioration. Likewise, in any climate calories and carbohydrates have to be eaten every day if men are expected to remain fit. Total deficiency of members of the vitamin B complex, especially thiamine, can begin to cause trouble in from one to two weeks. A very low intake of fats, protein and ascorbic acid can be tolerated for several weeks

without deterioration. Total deficiency of other inorganic substances besides sodium chloride, and deficiency of the fat-soluble vitamins can go on for months without serious effects on an active man. In planning field rations it should be remembered that active young men do not have to have a completely balanced ration every day. Over a period of months they do need it, but for periods of weeks they do not suffer from certain types of nutritional deficiency provided they were well fed at the beginning.

I should like to present an illustration from the Canadian Cold Weather Trials in 1944 of the tremendous importance of acceptability and the serious consequences of caloric deficiency in hard-working troops. This example is not intended as a general condemnation of any particular food, but as an illustration of certain very important factors affecting the adequacy of rations and of the methods we have used in studying them. Pemmican, a mixture composed of dehydrated meat

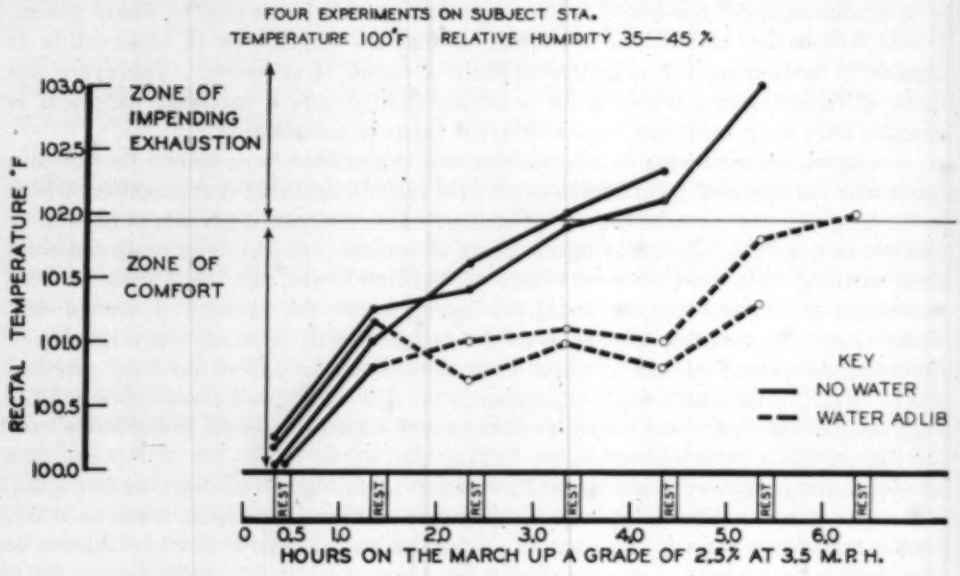


FIG. 1

and fat in about equal parts by weight, has been advocated by some as a desirable sole or major component of rations because of its high caloric density, ease of preparation and stability. During the trials four seasoned platoons were maneuvering against each other at a time when the mean temperature was —3° F. in the bivouac area. Three of the platoons received orthodox types of field rations. The fourth and best, led by an excellent officer experienced in bushcraft, received pemmican, black tea, and cigarettes. Daily tactical exercises consisted of simulated combat, marching and hauling toboggans over broken, snow-covered country. At the end of the first day on pemmican morale had dropped, there were complaints about the food, and over half the men complained of nausea. The second day required 13 miles of pulling toboggans over deep snow. Excessive fatigue became apparent and half the platoon complained of weakness. The third day brought them to the point of disintegration as a military unit. There were several exhaustion casualties that had to be evacuated and by the end of the day the survivors could hardly march at all. From a fit, alert platoon they had become operationally useless because of caloric

deficiency caused by inability to eat food enough to enable them to work hard. If they had been in actual combat against the other three platoons they would have been decimated by the end of the second day because the other platoons remained fit. Examination in the field laboratory showed a weight loss averaging 7 pounds in three days, dehydration, low chloride reserves, and a gross acidosis, as judged by the presence of large quantities of acetone bodies in the urine when tested by the nitroprusside reaction. A quantitative test of fitness for hard muscular work, in which subjects step up and down at a fixed rapid pace while carrying a heavily loaded pack, showed that physical fitness had become very poor (Fig. 2). They were fed a pure carbohydrate diet on the fourth day and revived remarkably on an

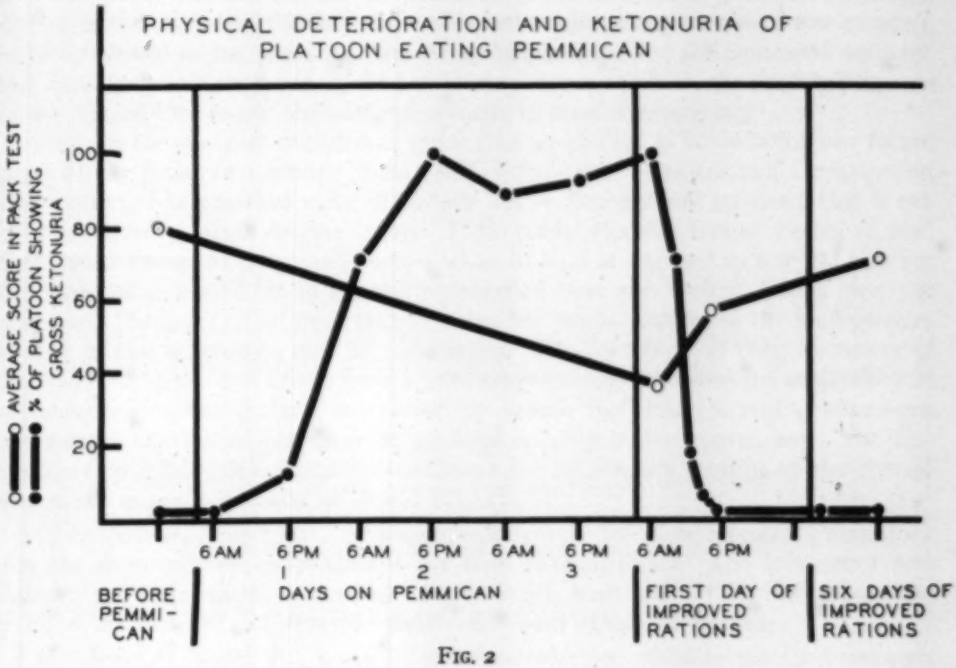


FIG. 2

average caloric consumption during this one day of about 7,500 per man. They were sent back out on maneuvers with a ration that contained the same pemmican but in addition sugar, salt, canned milk, oatmeal and biscuits. They performed quite well and cooked up stews, soups and hashes in considerable variety which they could eat with some relish. We concluded that pemmican alone is not a suitable field ration for infantry troops, and a subsequent complete search of the Arctic and Antarctic literature showed that whenever parties have tried to use pemmican as the sole component of their rations, they have encountered trouble or disaster. When used in conjunction with a variety of other foods, it has been useful in trail rations.

We saw an example of a successful field ration in the Philippines in May, 1945. The 38th Infantry Division had been 4½ months in continuous action against the Japanese, and had lived on the new C ration during all this time. Physically, they showed some wear and tear and a loss in average weight of about 10 pounds in the previous 6 months, but their military efficiency, morale, physical fitness and biochemical status were all good. The new C ration was still fairly palatable to them. The explanation, to our minds, was that it had received an adequate field trial in

Colorado in 1944 to screen out unacceptable items before it was procured in quantity, and it contained a variety of well-prepared items, such as chicken and noodles, pork and beans, and hamburger patties, which were similar to foods Americans eat voluntarily at home. By the end of the war, therefore, it had been demonstrated that a satisfactory compromise can be made between the necessity for non-perishable rations and the necessity for highly acceptable foods.

REFERENCES

1. JOHNSON, R. E. Gastroenterology *1*, 832-840 (1943).
2. KARK, R. M., JOHNSON, R. E., AND LEWIS, J. S. War Med. *7*, 345-352 (1945).

UNIVERSITY OF MINNESOTA LIBRARIES

THE TRANSITION OF ARMY FOOD RESEARCH [1]

COL. ROHLAND A. ISKER
Former Commanding Officer,
QM Food and Container Institute, Chicago, Illinois

There has been much in the papers in recent months concerning Armed Forces research and development for the national security. There have been discussions of various bills before Congress that have for their purpose the establishment of national research agencies. The Army and Navy in their various activities have taken steps to provide the research and development that they feel is necessary for their activities. It is only natural for the members of the Institute of Food Techonology, cutting across as it does the food industries and research institutions of this country, to be interested in the plans that the Army has in mind for the continued research and development in food during the peacetime years as it affects the feeding program of the Armed Forces and the national security in time of emergency.

Perhaps the soundest criterion or guide that we can use in formulating our future plans can be found in a history of the QMC Subsistence Research and Development Laboratory. The practical value of history lies in the help and guidance that it can offer in devising plans for the future. How ready was the United States to feed the Armed Forces at home and abroad when in 1941 it engaged in a world war for the national defense? It is generally conceded that the United States was not prepared. However, it is important to know the precise nature of the inadequacies so that proper safeguards may be undertaken. The Secretary of War, Secretary of the Navy, Congress and others have a joint responsibility to insure the availability of sufficient appropriations and provisions to permit the research and development and related operations necessary to national security and preparedness. The discussion that follows is a status summation of the subsistence position of the Armed Forces at the commencement of World War II.

Organization. The QMC Subsistence Research and Development Laboratory was the sole military establishment for food investigations. The laboratory had virtually no equipment, a handful of personnel, and had for its objectives the training of subsistence officers and the development of special rations.

Mobilization Plans. A plan had not been devised to mobilize the food research and development and production resources of the country. An adequate approximation of what constituted the technical subsistence problems had not been formulated. Provisions for this type of activity had not been authorized as evidenced by the lack of technical facilities, personnel, and budget.

Subsistence Training. Initially (1941) the laboratory was responsible for training subsistence officers. This was only spasmodic until 1944 when the training responsibilities were undertaken by the QM Subsistence School. The training program was inadequate in scope by not providing instruction for:

a. Staff officers in the principles of research and development.
b. Instructors of subsistence courses including inspection.
c. Technical officers for assignment in the laboratory.
d. Officers for assignment as overseas observers.

In addition, there was no centralized technical agency to review the subsistence courses that were offered throughout the services to insure that the latest technical information was being employed.

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

Feeding Programs. The responsibility for "A" and "B" ration feeding was not centralized. The laboratory had for its objectives only the development of B ration components and special packaged rations. Because of the small staff, short existence (1936), and virtually no budget ($750.00 per year), the only rations that had been designed by the commencement of World War II were the old style "C" ration and the "D" bar.

Overseas Observers. Virtually no information was available to the laboratory on allied and enemy rations, containers, and subsistence equipment. There were no provisions for laboratory overseas observers. Liaison channels were obscure for a long period and were never entirely satisfactory since the officially designated observers were not technically qualified in subsistence. As a consequence, the determination of military characteristics for foods, rations and containers was long delayed. A considerable savings and improvement in rations could have been effected earlier if the personnel who are responsible for subsistence, research and development were permitted to make their own field observations. Considerable time was lost in attempting to design needed operational rations with no realistic information based on first hand observations.

Food Products. Little or no information existed on the merits of commercial items for Armed Force use. There was virtually no information on the available facilities for the manufacture of food products or for industrial research and development on foods. Considerable time was consumed in establishing contact with the food and related industries. Additional time was consumed in attempting to develop a production research and development organization for the purpose of coordinating technical military food requirements with industrial research and development and production efforts. Research and development had to commence at the same time large scale production was required. Plants were constructed before needed technical information was available, with the result that products were produced that did not have appropriate military characteristics. Once the plants were constructed it was difficult to make changes, especially when materials were scarce and trained personnel were at a minimum.

Subsistence Specifications. Federal specifications for food and related packaging were not adequate for military use. In most instances the federal specifications were years out of date. In general, they represented the marginal producer's operations. It was, therefore, necessary after first determining the characteristics required by the military for various food products to investigate plant operating conditions so that specifications could be written which would permit only the best equipped manufacturers to comply with the exacting requirements. This was deemed necessary to obtain food of not only the highest initial quality but also food that would retain its stability under the conditions imposed by military operations.

Quality Control and Inspection. Analytical methods for the quality control of subsistence were in many cases lengthy or did not check sufficiently close in official collaborative tests. In most cases standardized inspection procedures and representative sampling methods had not been devised. Very few subsistence plants were equipped with laboratories. Quality control is a responsibility of the manufacturer. Ordnance has developed methods whereby the manufacturers test their own production instead of sending samples from the plant to central Army testing laboratories. This saves days in determining the acceptability of specific production lots which are frequently urgently required to meet shipping date deadlines.

Containers. The United States had virtually no experience on overseas shipment of subsistence. Adequate packaging, packing and crating information did not exist.

In the first year of the war commercial containers were used, resulting in millions of pounds of subsistence that never reached its destination point in an acceptable condition. The tin and rubber shortage created numerous research problems in an attempt to find workable substitutes. There were no provisions for standard markings of cases, standard sizes or, for that matter, standard packaging, packing, and crating for military foods and rations. Performance tests or even the performance requirements for containers were not known. It is literally true in the first months of the war subsistence was shipped in orange crates and egg cases.

Subsistence Equipment. The development of field and garrison equipment required in messing operations was and still is decentralized from the laboratory. An excellent opportunity had been lost to adapt, revise, and develop equipment in cooperation and conjunction with investigators who are responsible for the research and development of the products for which the equipment is required. The performance requirements of refrigerators, ovens, ranges, etc., should be based not only on logistics but on the functional characteristic of food.

Food Preparation. Here again an inadequate staff and laboratory facilities prevented the advance publication of needed information on the handling of frozen and dehydrated foods in addition to urgently needed methods for preparing meals for large groups of men with the use of field and garrison equipment. Thousands of untrained men were converted overnight into Army cooks. The need for simple, fully-illustrated bulletins and manuals was essential to a successful feeding program.

Fundamental Food Research. The United States had no central research and development agency designed to provide fundamental information that could be applied to the improvement and development of new food products and rations. The activities of the Office of Scientific Research and Development did not include, except in one or two instances, any program for investigations bearing on foods. The National Research Council "Committee on Food Composition" performed an admirable service, but its function was advisory and its program limited in scope. It was not until 1945 that provisions for a Quartermaster Corps nationally coordinated Committee on Food Research was established to provide urgently needed information on:

a. Methods for improving and evaluating the acceptability of foods used under various operational conditions.
b. Methods of improving and evaluating the nutritional adequacy of rations used under various operational conditions.
c. The chemical and microbiological factors affecting stability of food and methods for their control.
d. Methods for improving the functional properties of foods.
e. Current critical literature surveys.

Reserve Personnel. The Quartermaster Corps had no provisions for obtaining or training within its reserves technically qualified officers. The largest bottleneck in organizing the laboratory staff was in obtaining the transfer and assignment of technical personnel from various services throughout the country. There was first the problem of ascertaining the technically trained officers and then attempting to effectuate their transfer or assignment. Undoubtedly the names of many qualified individuals were not obtained and many that were obtained were not available for assignment or transfer.

The Laboratory. Following Pearl Harbor, costly months that stretched into years were required to convert the QMC Subsistence Research and Development Laboratory occupying 10,000 square feet with little more than a tea kettle for equipment to the present establishment that extends over 80,000 square feet and

comprises one of the best equipped modern food and container research and development institutions in the world.

The School. The QM Subsistence School was designed by and physically adjoins the QMC Subsistence Research and Development Laboratory. The School is equipped to accommodate the subsistence training needs of the military. To date Navy, Marine, Air Force and Service Force officers have been enrolled in the courses.

The successful termination of hostilities has not terminated the need for research and development and technical training. A food research and development institute based on the already existing QMC Subsistence Research and Development Laboratory and the QM Subsistence School can provide the needs which have been listed in the historical summary and which are indicated for the future.

Food Essential. The feeding of the Armed Forces is a basic military responsibility, both in war and in peace, providing a major means of maintaining morale and health. In war it is one of the few limiting factors in Naval, Air or Ground Force operations determining either the radius, duration, or mobility of action. In peace, the Army and Navy must be adequately fed and trained in subsistence activities.

War of Science. Scientific and technological advancements produce a profound effect on strategy, logistics, and tactics. Resulting operations create new and complex material requirements which in turn must be referred to science and technology for solution. Custom-built foods, rations and related containers and equipment reflecting the maximum current scientific ingenuity must be available to supply a constantly changing performance requirements schedule.

Peacetime Operations. A vast amount of research and development on food will be conducted after the war by industry, research institutions, government laboratories, and associations. There will be a need for a clearing house to consolidate the latest developments in each field and to apply the knowledge to military feeding and training. In addition, investigations will be required which the military will be in the best position to perform. By integrating the research and development peacetime needs with a national preparedness program a double function can be accomplished. The maintenance of food specifications reflecting the latest industrial advancements alone can save millions of dollars per year to the government.

Training Needed. Because of the complex inter-related activities characteristic of military operations and because of the technical considerations underlying these operations, properly trained personnel are mandatory for efficient subsistence activities. Procurement, storage, transportation, distribution, supply, inspection, instructor, observer, scientific, technological, and staff planning officers require training in an integrated food and military science curriculum.

In attempting to modify and correct the inadequacies of our previous authority and responsibilities, a restatement of the expanded mission and major functions of the laboratory was submitted to the Office of the Quartermaster General for approval. It is of interest then to note that the now approved mission and major function of the QMC Subsistence Research and Development Laboratory, which effective 1 March 1946, has been redesignated and is to be known as the QUARTERMASTER FOOD AND CONTAINER INSTITUTE for the Armed Forces.

The mission and functions of the Quartermaster Food and Container Institute for the Armed Forces are as follows:

a. To design, improve, develop, and evaluate food products and rations suitable for military use, the packaging and packing of these items and in addition, the packaging and packing of all other Quartermaster Corps supplies, except fuel and lubricants.

b. To prepare, review, and amend Quartermaster Corps specifications for food products, rations, and the packaging and packing sections of all Quartermaster Corps specifications except those pertaining to fuel and lubricants.

c. To prepare for publication: manuals, bulletins, regulations, specifications and texts of a technical nature which pertain to food products, rations, and food preparation and the packaging and packing of all Quartermaster supplies other than fuel and lubricants.

d. To represent the Office of the Quartermaster General on Federal, military, and other specification boards, the National Research Council, the National Academy of Science, military testing boards, the U. S. Department of Agriculture, the Federal Food and Drug Administration, and any other national or international research or scientific organizations in technical matters dealing with the products and supplies mentioned in a above.

e. To administer a coordinated fundamental and applied research and development program with scientific institutions interested in the products and activities mentioned in a above.

f. To prepare and keep up to date plans to be used in time of national emergency, for the organization and expansion of activities relating to a above.

g. To maintain liaison with various agencies of the Armed Forces and to ascertain the status of current and proposed strategy, tactics, and logistics, affecting the research and development of applicable products and supplies.

h. To maintain contact with industry, universities, government and other laboratories, and maintain a suitable advisory and technical information program relating to the items and activities mentioned in a above.

i. To maintain a current library and library services on appropriate technical information.

j. To maintain a current summary of national and world resources required for the development of rations and the packaging and packing of all Quartermaster supplies except fuels and lubricants.

k. To maintain and operate mobile subsistence laboratories.

The affairs and destinies of the new Quartermaster Food and Container Institute for the Armed Forces are now in the hands of Colonel Charles S. Lawrence. He was especially selected by the Office of the Quartermaster General to be commanding officer of the new Institute. In the few short weeks that he has been on duty, the members of the staff have already learned that he is their friend and will support their work. Colonel Lawrence is not only sympathetic to research but a staunch supporter. He will welcome any assistance you, as individuals, or as an organization, can give him. I can also assure you that he is a grand fellow to work with.

GERMAN WARTIME FOOD PROCESSING AND PACKAGING[1]

R. W. PILCHER
Research Division, American Can Company, Maywood, Illinois

The weeks following V-E Day were not too well suited to observation of German food processing and packaging practices as they had been carried out during the war. Invasion of Germany proper in the early spring of 1945 had disrupted normal schedules of planting and production of certain food crops; much productive land had been diverted to military uses of the invading Allied armies; a severe manpower shortage existed due to the liberation of impressed or slave labor; railroad transportation facilities had suffered heavy damage, much of it inflicted by the German army, and a good part of the available rolling stock was required for Allied military needs. Further, the smooth flow of materials essential for food processing and packaging was disrupted by the zoning provisions of Allied occupation. Recovery from all these handicaps was slow; in fact, even now it still can not be considered complete, according to recent information from Germany.

Besides the limitations to observations outlined above, the time allocated to investigating missions was not long. This fact, coupled with the shortage of transportation caused by the removal of armies first, to the Pacific Theater, and second, after V-J Day, to the United States, required more hurried or less leisurely observation than was to be considered desirable. A further limitation to detailed conclusions on German food industries was the fact that many plants or processes were inoperative or only partially operative due to war damage. This was particularly true of establishments located in the vicinity of key German ordnance or munition plants.

It is still possible, however, on the basis of information obtained by our mission, to give broad descriptions of certain German wartime food processing and packaging practices with particular reference to how such practices compare with or differ from their American counterparts. While the final report of the mission, now in the custody of the Quartermaster General, covers a wide variety of standard and special processes and products including German army rations, the scope of this paper under existing circumstances must be limited to the practices of three major German food preservation industries, namely, those utilizing on a commercial basis the processes of freezing, dehydration and canning.

GERMAN FROZEN FOODS

General. In wartime Germany, frozen foods, apart from certain items such as meat and fish, were apparently utilized to a much greater extent by the civilian populace than by the Wehrmacht. In the case of civilians, frozen foods were reported to be definitely a luxury item because of their premium cost, and were generally available only to those who could afford them. This may in part have been due to the fact that full commercial production of frozen foods in Germany began shortly before the outbreak of World War II. This fact, well verified, came somewhat as a surprise. During the war and now, the industry is dominated by three large operators with freezing plants distributed throughout the three zones of Allied occupation.

Products. Although the German frozen food industry is relatively young, it produces an impressive list of products. In Table 1 is shown a partial list of foods frozen commercially which were either encountered or found described in the

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

operating schedules or instructions of the major operators. The extent of production of these commodities was never exactly determined; in the case of the fruit and vegetable products the 1944 production was estimated to have been somewhere in the vicinity of 45 million kilograms or 49,500 tons. As will be noted from the table, many of the items produced have American counterparts.

TABLE 1

Some German Frozen Foods

Apple slices	Kohlrabi
Apple sauce	Marmalades
Apricots (halves)	Mushrooms
Asparagus (whole and cut)	Peaches
Beans, stringless (whole and cut)	Pears
Beef	Peas
Blueberries	Plums
Blackberries	Poultry
Brussel sprouts	Raspberries
Carrots	Raspberry puree
Cauliflower	Rhubarb
Cherries (sweet and sour)	Spinach
Corn (cut)	Strawberries
Cucumbers	Strawberry puree
Currants (red and black)	Tomatoes
Fish	Tomato puree
Gooseberries	

Containers. For the most part, there is little new to report on the types of containers used to package German frozen foods. The most popular types were fiber cartons of the conventional folding variety varying from 250 grams to 8-10 kilograms in capacity. At the start of the war these cartons were inside and outside paraffined; inside cellophane liners were provided for syrup packed products, purees and marmalades, and outside cellophane wrappers were also commonly used. As wartime shortages developed, the outside cellophane wrapper was reduced in size to a narrow band around the center of the package. For the smaller cartons, as the quality of paper stocks declined, a large parchment bag, square in shape and capable of sealing was developed into which the cartons could be placed after freezing. A great deal of research on fiber and plastic packaging materials was carried out, particularly by the Institute for Food Technology at Munich, on characteristics such as permeability to air, water, water vapor, fats, food odors, and fruit acids. The effects of folding and creasing the materials were studied and the weight losses of various types of commercial cartons over long storage at freezing warehouse temperatures (—15° C. or 5° F.) were also measured. In general, it was claimed that a satisfactory package should prevent loss of more than 1.0 to 1.5 percent of weight during commercial conditions of storage in one year's time. The experimental materials studied by the Institute included a variety of nearly 40 different lacquered, laminated or impregnated papers, special papers, plastic foils or sheets.

The German fiber cartons used commercially appeared to offer no advantage over, if in fact they were consistently the equal of, similar packages used in America. One exception might be noted, namely, the so-called "Eco" carton, a rectangular, lap-seamed body container with countersunk ends sealed on by a heat-setting adhesive. The body and end stock used in this container consisted of 0.05 mm. aluminum foil laminated between paper (200 to 250 grams per square meter or about 40 lbs., basis weight). Tests showed this container, produced mainly in the

800 cc. or 750 grams size, to be excellent and it was subsequently used for some frozen and dehydrated foods (dried eggs) and also as one of the containers for the famous "Dauerbrot" for German army consumption. However, the method of handling this container which involved reforming the knocked-down body, applying the bottom end in a special hand operated machine with an electrically heated head, filling, sealing the top end and freezing required a degree of manual manipulation as well as time which would hardly be feasible in American commercial practice.

Operations. As previously stated, three major operators dominate the German freezing industry. In general, on the production of standard commodities by these producers there is little to report which represents new practice, but a broad description of certain items in the procedures might be of interest.

With respect to blanching, two schools of thought exist as to the relative virtues of boiling water and steam blanches. Steam blanching appears to be used to the greatest extent but some operators provide for the use of both methods. Where water blanching is employed, it is carried out at 100° C. and followed by ice water or cool water cooling. Proponents of this practice claim for it a more positive inactivation of undesirable enzymes, thus making possible the elimination of control tests for enzymes after the blanching operation. To reduce loss of soluble nutrients to a minimum, as a rule of thumb it is recommended that the cooling time should not exceed two-thirds of the blanching time. In Table 2 are reproduced some ranges of blanching schedules used by German manufacturers.

TABLE 2

German Commercial Blanch Schedules

Expressed in minutes in water at 100° C. or in free flowing steam

Product	Water	Steam
Apple slices	1.0 to 2.0	1.5 to 2.5
Asparagus (14-18 mm. stalk)	1.5 to 5.0	.....
Beans, green, cut	2.0 to 2.5	2.5 to 3.0
Beans, wax, cut	1.5 to 3.0	.....
Brussel sprouts	1.5 to 4.0	.....
Carrots, small	3.0 to 6.0	.....
Cauliflower	2.0 to 5.0	10
Celery	1.5	.....
Mushrooms, cut	1.5 to 5.0	.....
Mushrooms, whole	3.0 to 6.0	.....
Peas (9-10 mm.)	5/6 to 1.0	2.5
Spinach, spring	3/4 to 1.0	1.0 to 2.0

The two principal types of freezers employed in commercial German operations are based on the use of tunnels or cabinets. The cabinet type most commonly encountered froze the product in containers by cold plate contact; many of these freezers were of American manufacture and identical to those used in many plants in this country. Tunnel freezers were of variable design and were utilized to freeze either the packaged or unpackaged foods in trays as the packages or trays were carried through the tunnel. Depending upon the freezer design, the freezing air blast used in the tunnel was in the direction of the conveyor belt, counter to the belt direction or across the belt. The cabinet plate and tunnel freezers were made in both the stationary and mobile types. Other variants in freezer design included a circulating air cabinet freezer and a circulating air-plate type of mobile cabinet freezer, the latter being a fairly new development in freezing equipment. Ammonia was the principal refrigerant used in the installations seen.

Mobile freezing storage units were also utilized to transport frozen packaged foods from the freezers to freezing warehouses; the more pretentious of these had self-contained refrigeration units. Freezing compartments or refrigerated chests were also used for frozen food transport. Warehousing temperatures for frozen foods depended somewhat upon the product under consideration but for the most part would average close to —15° C. (5° F.). One set of recommendations to the industry specified the storage temperatures for various frozen products over a 12 month period shown in Table 3.

TABLE 3

Recommended German Warehouse Temperatures for Frozen Foods

Recommended maximum storage temperature or range (°C.)	Product
—10 to —15	Applesauce
—15 to —18	Tomato pulp, hog sides, mutton, poultry, sausage
—18 to —20	Gooseberries, plums, strawberries, melons, apples, pears, raspberries, blackberries, sweet and sour cherries, beets, spinach, rhubarb, cauliflower, peas, carrots, corn
—20 and below	Most fish products, asparagus, mushrooms, peaches, apricots

Other factory operations usually involved utilization of more manpower than is required in American practice for roughly comparable production, due to lesser usage of mechanical handling of raw and frozen products. Freezing times for the various packages were within the ranges of those encountered commercially for similar packages in the United States. Freezing temperatures were also within the usual ranges for the principle of freezing employed; one possible exception was the use of an air blast of —45° C. (—49° F.) in one type of tunnel freezer.

The Cold Chain. One wartime development which had received publicity outside Germany was the so-called "cold chain," a term coined to cover a complete system for the transport and warehousing of frozen foods from production to consumption. This system was well designed to take care of transport of frozen foods from the point of sale or production to the place of consumption. This ambitious system was to be provided by refrigerated or freezing ships, railroad cars, trucks, trailers and special cold boxes. The details of construction and recommended materials for the necessary transport and storage units were found to have been drawn up and well worked out; even costs of the various methods of transport had been cast.

In the early days of the war the cold chain apparently did not reach to the front line, but only to army camps, division headquarters, occupation forces in Norway, and so forth. Later, heavy German self-contained refrigerated transport, particularly ships and railroad cars, was lacking and dependence had to be placed almost entirely on well insulated cold boxes protected by temporary refrigerants. From available information, it does not appear that the cold chain, however well conceived, actually proved to be a major system of supply for the German Wehrmacht except possibly for fish and meat products.

Product Quality. Comment on the quality of German frozen foods as compared with comparable American products had best be guarded. Observations made on samples packed in 1944 or 1945 must be interpreted in the light of existing circumstances. In both years, attempts were made to produce as much frozen food

as possible, a desire which probably led to less critical selection of raw material than might have otherwise been the case. However, considering the fact that German agricultural production for freezing depends largely on the efforts of a large number of small growers using manual methods and slow transport, and further, considering the fact that German freezing practices on the standard food commodities appear to offer no advantage over American practices, it is questionable whether most German frozen fruits and vegetables would even in peacetime be considered high quality under American standards. This was distinctly evident in certain of the samples examined where discoloration, freezer burn and other defects could commonly be observed.

GERMAN DEHYDRATED FOODS

General. In wartime Germany, apart from commodities such as dried eggs and milk, the production of dehydrated or dried foods appeared to be mainly carried out in conjunction with the preservation of other foods. It was noted that dehydration was usually conducted in plants which also carried out the canning or freezing of foods, manufacture of specialty products, or in some instances, all three. By American standards, most of these establishments were small. While no exact estimate of the extent of over-all German dehydrated food production was obtained, the suggestion was that whatever the figure might be, it was the summation of a large number of small individual efforts in the field of dehydration. Reports were received of at least one large plant devoted mainly to dehydration, but located beyond the limits of the American occupation zone.

TABLE 4

Some German Dried Foods

Apples	Mushrooms
Bananas	Onions
Beans	Parsley
Beef	Peaches
Beef goulash	Peas
Beets	Peppers
Blueberries	Plums
Cabbage	Potatoes
Carrots	Raisins
Celery	Rosehips
Cherries	Sauerkraut
Chestnuts	Soups
Eggs	Spinach
Lentils	Tomatoes
Milk	

Products. A partial list of dehydrated foods produced in wartime Germany appears in Table 4. Major fruit and vegetable products being produced in the summer and fall of 1945 were potatoes, cabbage and peas, three of the most popular items.

Packaging. Many different containers for packaging dehydrated products were observed, varying from paper bags, barrels, simple paper wrappings, folding fiber cartons, laminated paper, and light and heavy cellophane wrappers to the Eco package previously described. No instances of practices in which the use of metal containers with atmospheric, gas or vacuum closure is mandatory were encountered. Some dehydrators utilized converted tile presses or specially designed presses to compress their products, dried vegetables, soups or specialty products, into briquets

which required only simple types of fiber wrappers. This compression, amounting to as high as 80 percent reduction in volume of the product, was claimed by German technical men to reduce the degree of protection against undesirable oxidative effects in storage required of the package or the wrapper.

Operations. From the records of equipment suppliers, it was estimated that between 800 and 1,000 commercial food dehydrators were in operation in Germany and the occupied countries in 1944. These dehydrators were the products of more than a dozen manufacturers, but the equipment made by two of them dominated the field. The dehydrators made by these two concerns employed the moving belt and the cabinet principles; the latter utilizing a counter current of air and the former relying on natural upward movement of heated air. Lesser used items of dehydrating equipment made by other manufacturers were largely variants of these two principles.

In the cabinet dehydrator, the food is introduced in trays at the top and progressively lowered against a current of heated air forced up from the bottom of the cabinet, rising at the rate of about 900 cubic feet per minute. The position of the tray was changed semi-automatically and the cabinet accommodated 10 of the trays. Large units of this type are claimed to handle, on a 24-hour operational basis, between 6,000 and 8,000 kilograms of cabbage, 7,700 to 8,600 of beans, and 10,000 to 12,000 of potatoes; these weights are on the raw material basis. The capacity of the belt type dehydrator was stated to be roughly similar by users of both types of equipment. The most popular belt dehydrator consisted of four belts mounted in vertical position so that the top belt onto which the food to be dried was fed by elevator discharged to the second belt; the dried product discharged from the bottom or fourth belt to the packaging station. Some typical belt temperatures observed on this equipment were in the following ranges:

1st belt (top)	80° C.
2nd belt	70° C.
3rd belt	60° C.
4th belt (bottom)	50° to 60° C.

German food dehydrators strive to attain final moisture contents in their products within specified limits, and operated their available equipment to that end. Meats or meat products are supposed to contain an end moisture content around 8 percent or lower; the limit for the common vegetables was reported as 10 percent, but 5 percent was recommended for mushrooms, carrots, and spinach. Eggs, dried on a spray drier, were reported to be between 1.0 and 1.5 percent moisture immediately after drying and between 2.0 to 3.0 percent at the time of packaging in the Eco container.

Water blanching at 100° C. appeared to be favored for vegetables to be dehydrated. Practice was varied as to the times at 100° C. employed, but the schedules in Table 5 which were recommended to the industry are typical. For potatoes, it was stated that the slice should be 2 to 3 mm. in thickness for use of the above schedule.

Product Quality. Because of the obvious advantages which dehydrated foods offered to harassed Germany in wartime, since 1941 the development of this type of product received considerable attention from equipment suppliers, food dehydrators and research agencies. Samples of reconstituted products were examined from a number of sources and in many instances such samples were of fairly recent production. Where direct comparisons with similar American products were possible, recent German-made dehydrated vegetables when reconstituted, appeared

to fall far short of the claims commonly made by their producers, namely that they closely resembled cooked fresh vegetables. Again, as in the case of German frozen foods, low quality raw materials may have influenced the consideration. However, the 1944 products of even the best equipped dehydrated food manufacturers commonly exhibited defects which by 1943 had been largely overcome in American practice.

TABLE 5

Some Recommended Water Blanch Schedules for German Dehydrated Vegetables

Product	Seconds at 100° C.
Cabbage	60 to 100
Cabbage, winter	40
Peas	40 to 80
Beans, green	90
Kohlrabi	150
Celery	90 to 150
Potatoes	100

The high quality of German dehydrated eggs had been observed during the war by the Q.M.C. Subsistence Research and Development Laboratory, and was investigated by this mission. Limited observation of the manufacturing process suggests that the reason possibly lay more in acceptance of a lower drying temperature and slower production rate than in the drying or packaging techniques.

GERMAN CANNED FOODS

General. German canning operations during the war were conducted in all three of the zones now under Allied military occupation. However, the fruit and vegetable canning industry appears to have been largely centered in the Braunschweig-Hannover-Seesen area in Northern Germany. Likewise, the manufacture of cans for thermally processed food products also appears to have been located principally in that region; the same holds true for the manufacture of canning and can making equipment. Large meat canneries were located at Dachan, Kulmbach, Berlin, and in the Hamburg area.

By American standards, most German canneries are to be considered rather small establishments. Less than one-half dozen plants were found which, from the standpoint of equipment and volume of production, could compare with good sized American canneries; one of these concerns, operating two plants produced a total of about six million kilo cans of peas in 1944 or about 360 thousand cases on the basis of American number 2 cans. The majority of the smaller plants produced from 100,000 to 500,000 kilo cans in the same year. Available records indicated that the total kilo can usage for thermally processed foods in 1944 was about 500 million cans; this volume of can production could have been obtained by a single, reasonably large American can making plant in one year of extended operation. The small German canner may also engage in freezing and/or dehydration, marmalade manufacture or in a few instances in sausage making.

It was interesting to find that Germany possessed organizations roughly parallel to the National Canners Association and the Can Manufacturers Institute.

Products. In Table 6 are listed the major thermally processed foods produced in wartime Germany. As will be noted, the diversity of products is fair, but the list does not include the wide variety of specialty or many other canned products produced commercially in this country.

Containers. The principal can used for heat processed products (fruits, vegetables, and meats) was the kilogram or liter can. This was an open-top sanitary style of container, approximately 99 mm. in diameter and 123 mm. in height. This can corresponds roughly in dimensions to the American number 2½ or 401 x 411 can as it is commonly known in this country. The 99 mm. diameter can was also made in several other sizes. The "half size" height was 63 mm.; two other cans in the 99 mm. diameter were 25 and 180 mm. in height. The third can size, apparently used principally for fish and meat, was known as the 200 gm. can and measured approximately 75 x 63 mm. in diameter and height, respectively.

TABLE 6

Principal German Canned Foods

Apples	Mushrooms
Applesauce	Milk, evaporated
Apricots	Peaches
Asparagus	Pears
Brussel sprouts	Peas
Cabbage	Pickles and cucumbers
Carrots	Plums
Celery	Rhubarb
Cherries (black and red, sweet and sour)	Sauerkraut
Fish (lobster, shrimp, herring, fish roe)	Sausages (all types)
Green beans (cut and whole)	Spinach
Meats (beef, pork, mutton and fowl)	Tomatoes
Meat and vegetables (beef, potatoes, green beans or peas)	Tomato paste

Due to the urgent necessity of tin conservation, beginning about 1939 German can manufacturers explored the possible use of substitutes for hot dipped tinplate. Under direct stimulus from the OKH or the German High Commnad, the use of electrolytic tinplate was first studied. Available information suggests that investigation of this type of plate was not nearly as comprehensive or complete as that which was begun in the United States as early as 1937. Black iron plate was also investigated for use in cans for heat processed foods. To permit soldering the can body at the sideseam, the proposal was first made to coat the edge or margins of the black iron body blank with tin. Since this practice also involved the use of tin both on the body blank and in the solder, it was ultimately abandoned. A can with black iron ends and a welded sideseam black iron body was finally developed in the kilo or liter size can. This can was available both bonderized and unbonderized; it carried one external and two internal coats of enamel and was variously known as the A-2 or "Sila" can. The "Sila Special" can bore one external and three internal enamel coatings. The term "Sila" used by one can manufacturer was coined from the words "Sintered Lacquered" which referred to the relatively severe bake applied in can manufacture. Compound based on synthetic resins was applied to the manufacturer's end of the can; the packer's end compound consisted of a synthetic rubber ring. Arrangements were made for samples of the Sila Special cans and closing tools to be shipped to the Quartermaster Laboratory for test and comparison.

In addition to black iron cans and some electrolytic and hot dipped tinplate cans, aluminum cans were also used for specific products, notably milk and meat products. Samples of these containers made by both drawing and impact extrusion were returned for inspection by the Quartermaster General.

Operations. It was early apparent from the standpoints of raw product production, equipment, mechanization of equipment, and general operations that the

German canning industry lags far behind its American counterpart. From the quality standpoint, a possible exception might be made in the case of certain canned meat and sausage products produced mainly for SS and Kriegsmarine use; certain of these products were excellent and in many instances have no exact parallel among American canned meat products.

Except for the larger operators who appeared adequately equipped with conveyor belts and elevators, most German canneries depended upon manual transport of materials from station to station or machine to machine. German canning equipment, while very substantially built, operated on familiar principles. The most unique item of equipment noted was a meat dicer which, it subsequently developed, was already known to some American manufacturers. German canning operations are notable for complete absence of exhaust boxes, although vacuum closing machines were found in some meat canning operations. Only one exhaust box was seen which was in the process of construction for use in the 1946 season. Blanchers were mainly of the revolving drum type operating in water at 100° C.; most peas and green beans seen were severely underblanched by American standards. Vining of peas inside the plant is common, and low closing temperatures (60° F. to 100° F.) were universally encountered.

Unlike usual American practice, can closing machines are the property of the canner and a wide variety of such machines, mostly of the slow, semi-automatic type and operating on all common closing principles was found. Retorts, usually of 400 kilo can capacity, were entirely hand controlled; apparently an "automatically" controlled retort in Germany is one with a visible or recording thermometer attached. Some operators control a number of retorts at a central control board. Retorts are usually brought up to temperature slowly and blown down rapidly; this practice coupled with low closing temperature commonly resulted in strained or buckled ends to an extent considered hazardous in American practice. This situation probably would have been worse but for the fact that the kilo can end stock was of heavy plate (95 to 107 lb. plate). Both water and air cooling are employed; no pressure cooling even of heavily processed conduction heating products, was observed. Processing was carried out at both 116° C. and 121° C., corresponding roughly to 240° and 250° F.

Varied stories were received as to the suitability of the German bonderized and unbonderized black iron containers widely used in Germany since 1942. The larger operators clearly recognized the superiority of the prewar plain hot dipped cans for fruits over either of the two types of black iron cans. Smaller operators reported complete satisfaction and low corrosion spoilage rates with black iron cans even when used for acid foods (sauerkraut and rhubarb) and it is quite possible that they were entirely sincere in their statements, since some of them did not consider a 10 percent loss from all causes as excessive.

Temperatures in North and Central Germany, where most of the fruit and vegetables are canned, are cool, particularly at night. Canned food warehouses in these localities are substantial in construction, usually being built of stone or brick. This type of construction favors cool storage which quite likely retarded corrosion of the black iron containers. Likewise, the turn-over of German canned foods is rapid and the storage life of most canned foods is estimated to average about 7 months. These factors of low storage temperature and rapid turnover may have operated to permit more successful use of the black iron containers where a similar type of can under conditions of storage and usage prevailing in this country undoubtedly would have given trouble with certain acid and semi-acid products.

Product Quality. In surveying this question both of canned food and can quality, it appeared that both the German consumer and the German canner are far less critical of the quality of the finished product and the appearance of the container than is the case in the United States. In many instances, the 1944 packs, which were made at a time when presumably adequate manpower was still available, overmaturity and extraneous materials were consistently to be found. In the 1945 packs, besides canning defects, an excessive number of strained and buckled ends, dents and badly rusted end seams were to be observed in warehouse stocks. Apparently, these defects in the container after processing are not considered objectionable by the German canners or consumers.

As in freezing operations, raw food materials for canning are the products of small growers plagued with lack of machinery, rapid transport and manpower. This situation, coupled with the desire to preserve all the food possible in anticipation of likely famine in the winter of 1945-1946, has brought a lowering of quality in the standard German canned food commodities. Certain meat products might possibly be considered exceptions, as previously stated.

CONCLUSION

Excepting certain products designed primarily for German military use as well as certain other products of a specialty type, it was concluded that in general the wartime German freezing, dehydrating and canning industries were not the equal of similar American industries from the standpoint of volume of production, operations, quality of final product or package, or methods of packaging. While this statement is intended to apply primarily to the standard food commodities, at the same time there appears little question that these industries as they now exist play an important part in the food economy of the German people. It was unfortunate that the late start of food processing and curtailed production, due to the lack of necessary supplies of raw food stocks and other factors, did not permit these industries to operate in 1945 to their fullest capacity. Even so, without the products of these industries, considerable more hardship would have been suffered by the German people than has been reported for the winter of 1945-1946.

ACKNOWLEDGMENT

Appreciation for review of this paper is expressed to Colonel Rohland A. Isker, Retired, formerly Commanding Officer of the Q.M.C. Subsistence Research and Development Laboratory, Chicago, and to Dr. David Bruce Dill, Harvard University, who as Lt. Colonel D. B. Dill served as Chief of the Technical Intelligence Branch, Theater Service Forces, European Theater. Appreciation is also expressed to Miss Betty McGarry for help in preparation of the manuscript.

GERMAN MEAT PACKING AND FATS AND OILS OPERATIONS DURING THE WAR PERIOD [1]

GEORGE T. CARLIN
Swift and Company Research Laboratories, Chicago, Illinois

The United States Investigating Committee covering food products was organized directly by the United States Army. It was one of many committees of civilians whose duties consisted of the investigation of technological developments within Germany. It should be emphasized that members of the committee on food traveled as representatives and members of the United States Army and, as such, had no official connection with private American business. Attempts were made by the Army to assign committee members to industries in which they had particular skills. This was not always possible but for the most part the committee members worked either in their specialties or in fields allied to them.

STRUCTURE OF THE GERMAN MEAT PACKING AND FATS AND OILS INDUSTRIES

Contrary to American custom, the fats and oils industries and the meat packing industries were not allied in Germany. The meat packing industry was engaged in little, if any, production of fats other than small quantities of lard and rendered beef fats. In most cases, the meat packing industry did not even produce rendered meat fats for consumption as such. The German meat industry produced only edible meat products while the German fats and oils industry consisted principally of processors of vegetable oil seeds and of manufacturers of margarine. In no instance was found the combination businesses so economically desirable in the United States.

STRUCTURE OF THE MEAT INDUSTRY

The German meat industry included several hundred small to medium sized independent meat packers and canners. Such firms were located largely in country areas near the source of supply. They were engaged in the complete operation from slaughtering to meat curing, meat canning and small scale lard rendering. They were of particular importance as canners of meat for the German army. None of the independent German meat packing plants even approached in size the larger American plants. In fact, the largest German plant, Effa of Berlin, slaughtered approximately 3,500 to 4,000 hogs per week as a normal operation. There were three or four other independently owned plants approaching the capacity of the Effa organization within Germany but the average plant slaughtered only 800 to 1,200 hogs per week and approximately half that amount of beef.

In addition to the independently operated packing plants, municipal slaughter houses are found in practically every large German city. These plants are operated under the supervision of the municipality and are engaged in the slaughtering of animals for individual butchers located within the city. No processing, other than slaughtering, is carried on in the municipal slaughter houses.

As adjuncts to the independently owned packing plants and municipal slaughter houses, there exist in Germany perhaps 100,000 processing butchers. These individuals are engaged in meat curing, sausage manufacture, as well as the merchandising of fresh meats. Most are equipped with small curing cellars and smoke houses. A few of the private butchers are also equipped with meat canning and

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

processing machinery and produce a few specialties in addition to their normal production of sausage and fresh meats. This widely spread operation of small plants will perhaps explain the reason why the German meat industry is an industry of artisans, chefs, and butchers, rather than an industry of food technologists. It lags far behind the American meat packing industry in terms of efficiency, of utilization of by-products and in certain mechanical features.

The German fats and oils industry is not as widely scattered as the meat industry. It is centered around the North Sea coast of Germany at Hamburg, Harburg, Bremen, etc. Differing from the meat industry, the fats and oils industry consists of highly developed, large factories. The size of the individual plants compares favorably with that of the largest American producers and in one or two instances might even excel. This industry is dominated by one firm which is also engaged in the processing of fats and oils in the United States and Great Britain. Hence, methods used in Germany in the main were similar to those found in the United States. In some respects, the equipment in German fats and oils industry excels that found in the United States. An analysis of the specific points of difference between the German industries and their American counterparts follows.

THE GERMAN MEAT INDUSTRY OPERATIONS

It was difficult to analyze the operations of the German meat industry because of the almost complete absence of livestock in Germany at the time of the survey. Germany was without livestock fit for slaughtering purposes, and was particularly short of hogs, chicken, and beef cattle. About the only slaughtering operations were the dressing of cows, field oxen and some horses, and a sprinkling of hogs and beef cattle. The shortage of grain during the last year of the war led to the elimination of most grain-consuming livestock. For that reason, Germany today is desperately short of meat of all types. The German farms are also short of breeding animals and are without grain for animal production even should breeding animals be shipped to them.

The normal German livestock slaughter is approximately 9,000,000,000 pounds per year, with two-thirds of this weight made up of pork. Available stock plus breeding animals produced in 1944 nearly 5,000,000,000 pounds of meat products, or approximately 55 percent of normal. Present production is estimated to be about 10 percent of normal, with no prospects for immediate improvement.

Sanitary practices of Germany are fully equal to those of the better United States plants. Each plant maintains complete veterinary inspection services for the detection and removal of all unfit or diseased animals. Both ante and post mortem inspections are required in all German plants. It is noteworthy that the percentage of uninspected animals slaughtered in Germany was reported to be less than 10 percent for hogs and under 0.5 percent for beef during the years 1936 to 1941. Splendid examples of what can be accomplished by good housekeeping methods were common. There was no evidence of neglect in spite of the shortage of chlorine compounds for sterilization, soaps, etc. Aluminum, chrome steel, stainless steel, ceramic curing vats, glazed brick, and white tile were the rule rather than the exception. Machinery in most plants was found to be in good condition and scrupulously clean. One feature of German animal inspection was the almost complete disregard for possibilities of trichinosis. Much sausage in Germany is consumed in a raw state and since such products are composed essentially of pork, an attempt was made to determine the incidence of trichinosis within the country. Only ten or twelve cases were reported in 1938. This gives some semblance of accuracy to the German meat inspectors' claim that trichinae can be

detected by inspection of the diaphragm of the pig. It is more likely, however, that German hogs are not common carriers of this parasite.

FROZEN MEATS

Frozen, boneless, packaged meats played only a minor part in the provisioning of the Wehrmacht. The German meat industry was not equipped to produce large quantities of frozen products. It should be pointed out, however, that the German army did not depend upon private slaughterers for its supply of fresh meats and fresh sausages. Fully equipped slaughtering and butchering companies accompanied the armies wherever possible. These units were supplied with livestock, both by shipment and from local levy. Animals were dispatched and prepared either as sausage or as fresh meat by these mobile packing plants. Freezing was, therefore, utilized only for storage of surplus products.

Of considerable importance was the storage of frozen hog halves. These hogs were split through the backbone in conventional style, washed with water, dried, and then frozen at a temperature of —7° C. They were then transferred into freezers of —15 to —18° C. temperatures. Such pork halves were stored as long as three years. German army specifications did not advocate storage for more than eighteen months. While German packers refused to acknowledge that pork fat on such frozen carcasses became rancid, an examination of products frozen in Denmark and transported to Germany in 1943 indicated that the practice was not entirely successful. The Danish frozen pork halves were found to be somewhat strong in odor and particularly rancid on the surface.

ARMY SAUSAGE PRODUCTS

The German army, as well as German civilians, consumed large quantities of sausage in smoked, cooked, dried and canned forms. It was estimated that in normal times approximately 40 to 45 percent of Germany's total meat supply was consumed in the form of one type of sausage or another. Nearly all German sausages were rich in meat fats. It was for this reason that German meat packers did not produce large quantities of lard. Instead of rendering fat for lard, most pork fat was returned to the sausage. It was, therefore, possible to carry fatty foods to the German soldiers in forms entirely acceptable to them. Obvious transportation and caloric advantages accrued from this practice, without causing the usual complaints associated with the fatty foods consumed by the American army. In view of German experience, it is believed that the United States army might profit by intensive research looking toward the production of sausage-type products which would carry high percentages of fat in forms palatable to the soldier. Over thirty specific types of sausage were prepared for the German army. These sausages provided not only a source of fat, but also a vehicle for some of the more undesirable meat cuts, such as tripe, kidney, liver, lungs, blood, etc.

CANNED MEATS

Canned meat products played an important role in the provisioning of the German army. More than fifty-eight products were prepared for army use. Four or five were of major importance and will be covered in detail. These were canned pork, canned beef, Schmaltzfleisch, liver sausage, and Bier Schenken (the equivalent of pork luncheon meat).

Canned beef and canned pork were very simple products. The German meat canners merely chopped the meat into one to two inch cubes, mixed it with salt and a very small percent of pepper, and with 3 percent minced pork skin. The Germans

evidently did not believe in preshrinking the meat by partial cooking before extruding it into the cans. Attention is especially called to the fact that only 1 percent salt was used in the formula. It should be emphasized that the salt content of all German canned foods was much lower than that used in the United States. Canned meats for African use contained even lower percentages of salt than those for European use. Only 0.025 percent pepper was added to these very plain products. It was claimed that the German army was aware of the fact that troops quickly tire of spiced foods and for this reason kept their major meat products as plain as possible. Three percent of finely minced pork skin was added when available to provide a gelatinous absorbent for the juices which cooked from the meat during canning. This was insufficient to do much good because both pork and beef contained a sizable amount of purged liquid.

Another interesting product was Schmaltzfleisch, which was nothing more than canned pork. The product was made up of the entire hog carcass, including all of the fat, forequarters, hindquarters, belly, side meat, etc. The specification for the product required it to contain not less than 50 percent rendered fat in the form of lard. It resembled Russian Tushonka to some extent. It probably would have been rejected by American troops because of its excessive fat content. It was used by the Germans both as meat and as a spread for bread. It was a valued component of stews, gravies, fried potatoes, etc. Because of its caloric value, Schmaltzfleisch was a valued army ration. It was simple to prepare and offered no production problem whatsoever. The American troops could possibly use a similar product as a component of their B ration providing adequate instruction concerning its value and use could be given.

Canned whole hams were prepared for both the German marine and army. In the United States this ham would be designated as a semi-sterile product and, as such, would be packed only for refrigerated storage. Nevertheless, the evidence is positive that the German hams were held successfully in non-refrigerated warehouses for periods of one to two years. One distinction was made, however, in that hams destined for African zones were packed with 0.25 percent sodium benzoate. Most of the manufacturers claimed that either non-benzoated hams or benzoated hams would keep under African conditions for at least one year. These hams were somewhat similar to the Polish hams shipped to the United States only a few years before the war. Attempts were made by the committee to obtain exact details of the processing of such hams because American packers have never been able to produce under-cooked products with such prolonged shelf-life.

Curing solutions for German canned hams usually contained 14 to 16 percent salt, 2 percent sugar, and 2 percent sodium nitrate. The use of sodium nitrite in the usual quantities was also permissible. Hams were cured by both arterial pumping and dry curing methods. If arterial pumped, enough solution was infected to make up 6 to 10 percent of the weight of the ham. Combination of arterial pump cures and dry cures were popular. Usually the pumped hams were boned and then dry cured for two to three days in salt-sugar mixtures. These hams were then smoked for 12 to 20 hours at a temperature of 25° C. in order to produce a very mild, smoked flavor. They were then pressed into shape by means of a hydraulic press and placed into a can of proper size. The vacuum was drawn after sealing by means of the pin hole-vacuum chamber method. As previously stated, African hams contained 0.25 percent of sodium benzoate. Any liquid added to the can also contained this quantity. The cooking process was very light indeed compared to the American process. Cooking temperatures seldom exceeded 85° C. A four-hour cooking period

at this temperature was deemed sufficient for a 10-12 pound ham for domestic consumption. If the ham was packed for African use, a double cooking period was given with a 96-hour incubation between cooks. In neither case was the cook considered sufficient to inactivate *Clostridium botulinum*.

CANNED BIER SCHENKEN AND CANNED JAGDWURST

Bier Schenken and Jagdwurst were the German equivalents of pork luncheon meat. Bier Schenken was made from 100 percent pork, and Jagdwurst was made from a mixture of pork and beef. Both products contained only 1 percent salt. They were seasoned lightly with pepper, garlic, and sometimes nutmeg. A number of cans were examined but in no case was there evidence of over-spicing. These products contained a normal amount of sodium nitrate and sodium nitrite. Three percent potato flour was added to both products in order to absorb the canning purge. In the case of Bier Schenken, 80 percent of the meat was left in the form of large pieces, approximately 1 to 1½ inches in size, while 20 percent of the meat was finely chopped to provide a binder for the entire mass.

BEEF AND GRAVY (BEEF GOULASH)

The German army used a beef and gravy which was somewhat similar to the American precooked product. In this case, the meat was precooked, gravy was made from the cooking broth and contained assorted herbs, such as laurel, pepper, onion, celery, etc. It was thickened with brown flour and added to the beef to the extent of 1 part gravy to 2 parts precooked beef.

BIERWURST-BACON PRESERVE

This product was similar to pork luncheon meat except that it contained 10 percent smoked bacon in order to secure variance of flavor and of texture.

VEAL OR CHICKEN FRICASSEES

A very fancy product for hospitals was made from either veal or chicken. It contained both raw and precooked meat, and approximately 1 part gravy to 2 parts meat. The gravy was made with mushrooms, a liberal portion of white wine, capers, and other soup herbs. It was strictly a specialty product in every respect. Contrary to previously described practices with the common rations, the Germans sadly over-flavored and over-spiced all of these very fancy fricassees. Similar foods were made from duck, goose, wild game, etc. Apparently the fancier products had not received the attention given the plain products by the army high command. From an American viewpoint these expensive products were hardly edible.

MIXED PRESERVES

The Germans canned a complete line of mixed products made of vegetables and meat. Principal products were beans and smoked pork, peas with potatoes and smoked pork, rice and beef, and cabbage and pork. They were canned for the common soldier and contained little meat based on American standards. Similar American products contain from 40 to 50 percent meat by weight. German products contained only 20 to 25 percent meat or less. Obviously, the quality suffered because of this deficiency. In most products, the meat was placed in the can in one piece. This gave a rather sizable piece of meat to an individual soldier but it created a problem of division if more than one soldier happened to be present. Since all products were packed in cans of 850 gram size, the problem of division was probably encountered.

CUTTING AND CHOPPING

Most German meat products were cut mechanically. A novel machine was used for cutting meat cubes. It worked on a hydraulic press principle which secured an extrusion of meat through vibrating knife blades. The extruded slices were then chopped by means of a rotating circular knife.

FILLING

Most German canned meat products were filled by means of semi-automatic extrusion-type stuffers. These stuffers were arranged to achieve a capacity of sixty 850-gram cans per minute with two operators. The value of vacuum closing machines seems to have been unappreciated in Germany for either canned meats or vegetables. An exception was the canned meat products for African use. Where possible, African canned meats were purchased from firms equipped to produce vacuum closures.

HEAT PROCESSING

With few exceptions, the German army meat products were given a uniform heat process of 100 minutes at 121° C. (about 250° F.) for the 850-gram cans. Usually the products were filled cold. For the most part, however, the small retorts were slow in coming up to processing temperature, and, in like manner, were slow during the cooling cycle. The basis for the 100 minute processing was determined by the German National Institute for Animal Products by means of inoculated packs. The meat products were inoculated with both aerobic and anaerobic organisms of unstated heat resistance and they were processed until they were bacteriologically sterile. Only 6 to 10 different products were investigated and the findings were then applied to all products regardless of differences in conductivity. When contrasted to cooking methods previously described for whole hams, it is apparent that the Germans found it necessary to cook comminuted meats and meat-vegetable mixtures much more thoroughly than the cook recommended for whole, cured ham. (The overall tendency of German meat canners was in the direction of underprocessing rather than safe processing.) In spite of this haphazard manner of sterilization, very little difficulty was encountered through spoilage. This might be explained by the low storage temperatures encountered throughout Germany. It is seldom that temperature of the stored product would ever rise above 25° C. and in most cases, non-refrigerated storage ran as low as 10 to 15° C.

DEHYDRATED MEATS

The German army became interested in dehydrated meats in 1942. This interest was influenced by three major factors:

a. Shortage of cans
b. Transportation troubles
c. Shortage of cured meats and sausage

Consideration was given to pemmican, canned concentrated meat (dried to 15-18 percent water content), and to meats dehydrated in various sizes and forms. No completely satisfactory product was developed. One plant dehydrated a mixed goulash which contained assorted herbs, spices, and vegetables in addition to dehydrated beef. This firm inactivated enzymes by stewing the meat before dehydration. Attempts were made to keep the meat in the form of thin slices by rolling and squeezing the pieces before cooking. This practice proved to be unsatisfactory. The precooked slices were then dried by means of a tray type dehydration. The cooked out meat juices were thickened with flour, potato meal, spices, etc., and returned to the meat before drying. The finished goulash was of poor quality, tough, misshapen, and of tallow-like flavor.

A second dehydrated meat product was much more palatable. It was prepared in two stages by the grinding of raw, lean beef through a 15 mm. plate, curing as for corned beef with 1½ percent salt (containing 0.5 percent sodium nitrate), and preliminary drying at 60-70° C. to a moisture content of 30 percent. The partly dehydrated meat was then ground through a 3 mm. plate and passed again through the dehydrating equipment to secure a final product of 5 percent moisture content. The equipment used consisted of a 4 cycle belt type dehydrator with an entrance temperature of 80° C. and an exit temperature of 50° C. The total drying time was 5 hours. The finished product was smoked in a conventional smoke house for 20 hours and was then compressed into cubes of 600 gm. weight by means of a hydraulic press operating at 4500 psi pressure. The packer had post war ambitions and was experimenting with mixtures of the smoked dehydrated beef with assorted vegetables. The quality was judged to be good.

SMOKED AND CURED MEATS

The short German supply lines did not require smoked hams and bacon of the type used by the United States Army. Nevertheless, smoked and cured hams, bacon and beef of long keeping qualities were prepared especially during the early stages of the war. Army specifications required a salt content of six percent in these products. They were cured for the most part by dry curing methods although combination vascular injection and dry curing was popular. While the smoking process was covered in the specifications on the basis of "a chestnut brown color" the normal procedure for all German packers was to smoke bacon for 20 days and hams for 30 to 40 days. This long smoking process was carried out at low temperatures (25° C. and under), and thereby produced a finished product of low moisture content. Packers were forced to guarantee smoked and cured meats for a six months period without refrigeration. The German cured ham made for Army use was somewhat similar in appearance and texture to the American Smithfield ham.

Cured, smoked beef chunks of 4 to 6 lbs. weight were prepared from beef rounds in the same manner as hams. This product was not popular.

MEAT SUBSTITUTES

An interesting meat substitute was prepared from paper mill and textile waste waters by means of microbiological methods. In the digestion of beech wood chips by means of the well known sulfite process an acid effluent was created which contained as high as five percent fermentable carbohydrates. The occurrence of these liquors presented a disposal problem of serious magnitude because of the extremely large scale wood cellulose textile operation. Such liquors were neutralized with lime and ammonia, pasteurized, and were then inoculated with microorganisms capable of rapid and desirable growths. Torulae yeasts were used to some extent. However, the mold *Oidium lactis,* was preferred because of its greater vigor and better flavor. Tanks of 50,000 liter capacity were used for the final mold development. The induction period was approximately 24 hours, and during this time all soluble sugars were exhausted from the liquors by the vigorous mold growth. The inorganic nitrogen was converted almost quantitatively to protein of very satisfactory biological value. The finished mold was removed from the liquor by filtration, was washed several times with pure water, sterilized by heat treatment, and then was seasoned and stuffed into casings as a sausage substitute. The product was also dehydrated and used as a protein base for soup mixtures, "meat" loaves, etc. Its flavor was judged to be fairly good, possibly superior to that of common brewers yeast. The Germans called the product Biosyn. They expect it to furnish a highly

desirable protein feed material for live stock in the post-war era. They claim that waste waters can be cleaned at a profit by means of this synthesis.

SOYA BEAN EXTENDERS

German meat processors reported sad results with soya flour when used for purposes of extending meats. They had tried various varieties, including debittered full fat flour and fat free solvent extracted flour. Their objections were based on flavor complaints. Soya beans, however, were not important items in the German food economy.

The best method developed for the extension of sausage products by means of soya beans was as follows:

1. Soak whole beans in cool water for approximately 36-48 hours or until beans begin to sprout. This practice was supposed to benefit both flavor and nutritional properties.
2. Cook soaked beans under steam pressure until tender.
3. Grind cooked beans to a paste and then blend with other sausage materials.

A maximum limit of 25 percent (weight based on cooked bean paste) was allowed in liver sausage and in a few other products. When allowances for moisture are made it is apparent that 8 to 10 percent dry soya beans represented the maximum used for this purpose.

FATS AND OILS

The history of the German fats and oils industry was a history of shortage from the very beginning of the war. Whale oil, peanut, palm, and copra oils made up the bulk of prewar German edible fats with the exception of butterfat. The blockade made Germany dependent upon European production of vegetable oils to a major extent. Because of climatic conditions, only rape and sunflower seed oils were produced in important quantities. These oils, especially rape seed oil, which made up the bulk of the supply, presented the German margarine industry with a flavor reversion problem quite similar (but to a higher degree) to the flavor problem encountered with soya oil by American margarine manufacturers.

Margarine, next to butter, is the most important household fat produced in Germany. It is sold in colored form without discriminatory taxation. Manufacturers are forced to identify their product by inclusion in the formula of some easily detectable substance. Before the war 1 percent sesame oil was used for this purpose. During the war, 0.2 percent potato flour was substituted for the sesame oil. The well known Baudoiun reaction was used to identify margarine containing sesame oil. The iodine-starch reaction identifies the present products containing potato flour.

German producers do not use continuous margarine equipment so popular in this country. The batch system is still followed. Churns are of conventional type and most chilling is accomplished by means of revolving steel chill rolls. The flaked margarine is then texturized by means of five or more chilled porphyrin rolls running in series for purposes of providing the necessary kneading action. Artificial flavors, particularly diacetyl and acetyl-methylcarbinol, are used by all manufacturers. Both monoglyceride type and lecithin emulsifiers have been in common use since 1927. The shortage of milk has eliminated it from margarine manufacture. All German products are milk free at this time. Because of flavor reversion difficulties, salt has been eliminated from the formula. Manufacturers claimed that salt, water, or other substances likely to carry manganese, magnesium, or copper impurities into the margarine greatly catalyze the tendencies of rape seed oil to revert in flavor.

In normal times, both rape and soya oils are excluded from German margarine. Hardened whale oil is popular as the hydrogenated fraction of normal margarine. Peanut, palm, and copra oils are blended for the soft oil fraction. Hydrogenated oils of two different melting points are used as a means of securing proper texture. The hydrogenated fraction of the oil mixture approximates 60 percent in summer and 50 percent in winter.

The Germans had no antioxidants capable of impeding or preventing the flavor reversion reaction. Citric acid was commonly used, but other substances, if available, had been cleverly concealed. The food law did not allow the inclusion of phenolic type antioxidants.

While on the subject of flavor reversion, it is well to mention that this difficulty was controlled with considerable success. The Germans approached it from all angles. Expeller temperatures and pressures were lowered when possible. In fact, German processors emphasized the belief that American seed extrusion expellers cause flavor troubles, especially with soya oil. Refining of crude oil was followed by four to six washings with hot water, sometimes used alternately with sulfuric acid, and sodium carbonate. Oil bleaching was carried out under vacuum. It was claimed that a heavy bleach with activated bleaching clay would retard flavor reversion. After bleaching, the oils, if hydrogenated, were re-refined and again water washed before deodorization. All deodorization was on a batch basis, and was controlled organoleptically by the examination of samples drawn from the deodorizer. It was apparent that the German attempts to control flavor reversion were not based on fundamental knowledge of its cause. Such control as was effected was empirical and emphasized careful work at each stage of the manufacturing process.

BUTTER

German butter consumption roughly parallels that of the United States. Normal consumption is approximately 22 lb. per year per capita. This is supplemented by the consumption of another 16 lb. of margarine and 20 lb. of miscellaneous fats including meat fats and fat bacons. German fat consumption at the time of the survey was approximately 10 lb. per year or a drop of more than 80 percent below the fat rich diet formerly enjoyed.

German creameries represented perhaps the most up-to-date branch of the entire food industry. Equipment for holding milk, pasteurization, churning, cheese ripening—in fact, all dairy equipment including packaging machines were, at least, the equal of their American counterparts. Perhaps the progressive nature of the German dairy industry can be explained by the large, governmentally subsidized research institute and farms maintained at Kiel and Wilhelmstefan.

In addition to the customary practices of butter churning, the German possessed two methods for the continuous production of butter. Both methods depended on mechanical equipment designed either to break or to reverse the cream emulsion.

The first method, known as the Fritze or Roth process, began with 45 percent butterfat sweet cream, and depended on high speed mechanical agitation at closely controlled temperature for the breaking of the sweet cream emulsion. Two sizes of this machine were in use. One produced 1200 lb. of butter per hour while the larger had a capacity of 3500 lb. per hour. The Fritze machine was of simple construction. It occupied not more than 40 square feet of floor space.

The second mechanical process was known as the Alfa method. It depended on the concentration of sweet cream to a butterfat content of 78 to 80 percent through the use of centrifugal separators and subsequent emulsion reversal by means of low

temperature chilling. A three-stage chilling unit was used. It was completely self-contained, and was designed somewhat like the Votator machines used by the American shortening industry. Close control of temperature was necessary to secure a reversal of the cream emulsion. The finished butter was not of normal texture because of the small size of the butterfat crystals. Alfa butter had a definite tendency toward oiliness. Nevertheless, Alfa butter was highly valued for its excellent keeping quality. Samples stored in wood tubs at 4° C. for a period of two years were tested and found to be of excellent flavor, in fact, not unlike fresh samples of only 12 hours age.

The capacity of the Alfa machine was small, approximately 600 to 800 lb. per hour.

The edible fat and oil production of Germany cannot be dismissed without reference to the synthetic margarine product (Prima brand), made by the Märkische Seifenindustrie at Witten/Ruhr. This product was known as synthetic butter. Drs. Manchof and Henkel of Henkel and Cie., at Dusseldorf, and Dr. Imhausen of Märkische Seifenwerke were interviewed concerning this outstanding development.

Production reached a volume of 200 metric tons (440,000 lbs.) per month in 1944. The Witten plant has an estimated capacity of 600 tons per month. An examination of margarine samples stored at room temperature for six months was made at Witten. These samples were of fairly good flavor, but seemed to have a very slight acroleic after taste. Other samples of "Prima" synthetic butter previously inspected in refrigerated condition at the Institute for Food Technology, Munich, were considered to be of very satisfactory flavor. In both cases, the flavor of the synthetic product was superior to the best that could be expected in samples of corresponding age made from either rape or soya oils.

The Fischer-Tropsch synthesis for the production of fat is utilized in the two ways, first with a cobalt catalyst designed to produce high yields of gasoline, and second, with an iron catalyst which yields a high percentage of long chain hydrocarbons. Low grade brown coal is the essential raw material. It is first coked in the production of fuel gas and by-products, and the residual coke is used for the Fischer-Tropsch synthesis.

If cobalt is used as a catalyst, carbon monoxide (from coke) can be hydrogenated directly at normal pressures, but if iron is used, a pressure of 10 atmospheres is required. The resulting paraffin "Gatch" is made up of hydrocarbons of varying boiling points. Only the fraction ranging in boiling point between 320° C. and 450° C. is used for edible fat production. As stated above, higher percentages of this fraction are obtained when iron is used for catalysis.

In the first step of conversion of paraffin gatch to edible fat, it is necessary to oxidize the hydrocarbons and waxes present in the mixture. This is accomplished by blowing with air for a period of 20 hours at a temperature of 180° C. in the presence of 0.2 percent potassium permanganate catalyst. The oxidation is carried out until approximately 35 percent fatty acids are present. It is not possible to go higher than 35 percent fatty acid content without decomposition.

After oxidation, the material is water washed, and the fatty acids are separated from the unoxidized gatch. Herein lies the greatest difficulties of the entire process. The fatty acids are saponified with either sodium carbonate or sodium hydroxide. A small percentage of the saponified fatty acids settles to the bottom, and unreacted paraffins collect at the top of the reaction vessel. A partial separation is thereby achieved. Pressure is increased to 20 atms. and the temperature is raised to 180° C. in order to break the emulsion and to release more fatty acid soaps. Unreacted paraffins are returned to the oxidation chambers.

The soaps are then steam distilled at temperatures ranging from 320° to 380° C. in order to remove traces of unoxidized paraffin. The resulting pure soap is hydrolyzed by treatment with 60 percent sulfuric acid. The fatty acids are then distilled at a pressure of only 3 mm. Hg. The distillation temperature at the start of the process is 120° C. and at the finish 320° C. The yield of fatty acids is approximately as follows:

C_4 to C_{10} acids	12-14%
C_9 to C_{20} acids	65%
C_{20} to C_{28} acids	14%
Residue	9-10%

The C_9-C_{20} fraction is redistilled to remove the C_9-C_{11} fraction. A loss of 6 percent occurs during this distillation. Short chain acids of C_5 to C_{11} chain length are used for low grade soaps after mixture with longer chain acids. Acids of chain length up to C_5 are lost, *i.e.*, formic, acetic, butyric, etc. It is estimated that a loss of 5 to 6 percent is due to the non-recovery of this water soluble fraction.

Fatty acids of the C_{11}-C_{20} chain length are then esterified by direct reaction with glycerol in the presence of 0.2 percent metallic zinc catalyst. A one percent excess of glycerol over the theoretical amount needed to form triglycerides is used. This reaction is carried out under vacuum, 20 mm. at the beginning and 2 mm. at the end. The total esterification requires about one hour. The temperature is maintained at 110° C. at the start but is allowed to rise to 200° C. maximum as the reaction progresses.

The final product is washed with medium strength sulfuric acid to remove the zinc catalyst (as $ZnSO_4$), and is then washed with hot water. Analysis of the final product yields the following results:

Melting point (open capillary)	35° C.
Iodine number	10
Saponification number	235
Non-saponifiable matter	0.2%
Hydroxyl value	8 to 10
Free fatty acids	0.5%

Interpretation of the above analytical results indicates the following:

1. The presence of predominant percentages of short chain glycerides C_{14} and under.
2. The near saturation precludes much additional hardening by hydrogenation.
3. The probable presence of mono and diglycerides, as indicated by the hydroxyl value.
4. A need to study the composition of the non-saponifiable fraction (only 0.2%).

After esterification the product is refined, bleached, deodorized, and handled in the same manner as other fats. Slightly higher deodorization temperatures are used than are customary for vegetable oils (200°-250° at 2 mm.), but aside from this fact, the oil is churned and put through the process of margarine fabrication in the manner previously described.

The total yield of fatty acids from paraffin gatch is 80 percent. The fraction of chain length C_{20}-C_{28} is used in lubricating greases, as plasticizers for high melting waxes, and in cosmetics.

Dr. Imhausen stated that exhaustive feeding tests in human subjects were made over a five year period by Dr. Prof. Flossner of the Reichsgesundheitsamt at Berlin. All results were favorable, indicating that fatty acid chains of odd numbers (C_9, C_{11}, C_{13}, C_{15}, etc.) are just as valuable for human nutrition as are the naturally occurring even numbered fatty acids. It was further claimed that Dr. Flossner obtained evidence that synthetic fats are of especial value in the feeding of diabetics. It is believed that acetone bodies cannot be formed during the combustion of fatty acids of the odd numbered carbon chains.

SALT AND ITS PLACE IN THE FOOD INDUSTRY [1]

J. A. DUNN
Diamond Crystal Salt Company, St. Clair, Mich.

Like the blocking back on a football team who, while never carrying the ball or receiving the plaudits of the crowd, makes it possible for others to do so, salt, when properly applied to food products, develops other flavors without itself being apparent to our sense of taste. Salt is thus preeminent as a supporting flavor, whereas very few food products should taste salty.

In determining the correct amount of salt to be added to a food product, it should be varied by small increments in a series of batches until the product begins to exhibit a salty character of flavor. Once this upper limit has been determined, the amount should be reduced just to the point where saltiness is not apparent. At this level most products are properly salted.

It is well known that other flavors are developed by salt—that is to say, our sense of taste is more keen in the presence of salt. It is possible to show on a practical level that flavoring ingredients may be used more efficiently where products contain the optimum quantity of salt. Thus, the amount of fresh orange juice and rind in an orange icing may be reduced if a small amount of salt is included in the formula. Since flavorings, in general, are the highest cost ingredients entering into food processing and since salt is usually the least expensive ingredient, attention given to proper salting frequently results in a somewhat lower cost without sacrificing either flavor or general eating quality.

Few food products should really taste salty. A pretzel is the outstanding example. I should point out, however, that some products which are normally thought of as being salty should not be salty. Sauerkraut is an excellent example, for properly made kraut of high quality tastes sour but does not taste salty.

TYPES OF SALT AVAILABLE

Although the most common type of evaporated salt is granulated, that is to say, cubic in crystal contour, flake salt is preferred for many types of food products. Flake salt is normally screened into several fundamental sizes, whereas granulated salt is normally sold to food processors as it comes from the vacuum pans. An exception would be in the case of granulated flour salt, which certain producers manufacture. Some of the physical properties of typical salt products are shown in the chart:

PHYSICAL PROPERTIES OF SALT

	Mesh size	Density (lbs./cu. ft.)	Flakes (per lb.)	Sp. surface (sq. ft./lb.)	Solubility (in seconds at 70° F.)
High grade (Alberger)					
1. Coarse flake	14, 20, 28	38	620,000	11.2	18.5
2. Cheese flake	20, 28	37	2,660,000	18.5	16.1
3. Topping flake	28, 35	40	4,420,000	24.6	13.2
4. Butter flake	35, 48	46	12,900,000	39.8	9.4
5. Fine flake	48, 65	57	28,600,000	52.7	7.2
6. Flour salt	thru 65	62	63,500,000	77.8	4.5
Common					
7. Medium (Grainer)	20, 28, 35	40	.....	.....	30+
8. Granulated (vacuum pan)	48, 65	75	5,500,000	26.8	19.8

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 18, 1946.

The figures in the foregoing chart indicate a rather wide variation in density varying from less than 40 lbs. to 75 lbs. per cubic foot. There is also a very wide variation in the number of crystals per pound. From the crystal count, the specific surface of these various products has been calculated in square feet per pound and, here again, we find variation over a rather wide range. The speed of solubility is definitely related to the specific surface. When the logarithm of the specific surface is plotted against the speed of solubility for a given type of production, as in the case of products 1 to 6 in the chart, the points all fall on a straight line. The speed of solubility, therefore, is determined principally by the total amount of surface exposed to the solute.

Solubility rate is also determined by the process of evaporation. There are inherent differences in solubility of flake salts of varying origin. This has been determined by screening various sizes of grains from a number of sources, determining the solubilities, and comparing the results. Why these differences exist is not definitely known, although there is some indication that the speed of growth of the crystal during the evaporation process may be an important factor.

IMPORTANCE OF CHEMICAL PROPERTIES OF SALT IN FOOD PROCESSING

Purity of salt is of considerable importance in food processing. The most common impurities are calcium, magnesium, sulphate, and traces of heavy metals, principally copper and iron. Although it is commonly recognized that pectin reacts toward the alkaline earths and sodium as a zeolite base exchanger, used for water softening, it is not so generally recognized that proteins and starches also react similarly. In the presence of small amounts of calcium (250-500 parts per million or even less), pectins, proteins and at least some of the starches react with calcium or magnesium, usually resulting in a firming or toughening action. The process of developing firmer packs of canned tomatoes by the addition of calcium chloride is becoming widespread. In most packs of vegetables, however, tenderness is sought rather than firmness, thus indicating that calcium and magnesium should be kept at a minimum through the use of soft water and pure salt.

It is well to think of pectins, proteins and starches as base exchangers. It is a relatively simple matter to remove the alkaline earths by replacing these ions with sodium through the use of soft water and pure salt. By this means, some of the physical properties of food products may be modified. We have shown in our laboratory that when fish products and vegetables are processed and the canned samples held in storage, the sodium enters the solid portion, whereas calcium and magnesium are dialized out and increase in the processing brine. The extent of removal of calcium and magnesium depends on the calcium, magnesium and sodium content of the processing brine. When calcium and magnesium contents are plotted against time, the curves are parabolic. Differences in toughness or firmness are of sufficient magnitude to be detected when the foods are eaten.

Bigelow and Stevenson (1923) reported on the effect of hard water in canning vegetables. They indicated that 200 parts per million of calcium will toughen canned vegetables significantly. They also reported that calcium in the amount of 250 and 500 parts per million in the processing brine caused significant lowering in the drained weights of canned beans. Variations of approximately 10 percent in drained weight were reported. It should be pointed out, incidentally, that salt will frequently contribute more calcium and magnesium to the processing brine than the hardness of the water used.

D. R. Briggs, working at the University of Minnesota, has shown that potato starch acts as a base exchanger. By dializing against pure sodium chloride, he produced acid starch that was substantially free from calcium. Swelling power, as determined by viscosity, was determined on this product. Samples were then titrated with sodium hydroxide and calcium hydroxide to a pH in the range of 7.0 to 8.0. Swelling power increased in the case of calcium until present in the amount of 5 parts per million, after which the curve dropped sharply, indicating some change in the physical properties of the starch grains. In the case of sodium hydroxide, swelling increased to a considerably higher level, the curve leveling off at about 9 parts per million. Subsequent increases in sodium did not cause a drop in the curve. Dr. Briggs has not as yet published these results but his work is still continuing.

Let me emphasize that the calcium vs. sodium exchange is a reversible reaction and it is possible to carry a sample through several cycles. It is interesting to follow the changes in physical properties. Thus, a slice of beet becomes limp and almost translucent where calcium is completely removed but regains its normal properties when calcium is present at the proper level, excessive amounts of calcium causing toughness.

Tressler (1920) has shown that calcium, magnesium and sulphates, as impurities in salt, retard the penetration of salt into fish during curing. He also showed that salts containing these impurities cause fish to spoil during salting at lower temperatures than salts not containing such impurities. More recently, Ernest Hess (1942) has shown that impurities in salt affect the keeping quality of cod press-juice. The production of trimethylamine was measured as an index of spoilage through breakdown of protein. Shelf-life of fish products, therefore, may be extended in some measure through the use of salt of high purity. On the practical level, I have recently shown that herring fillets will be struck during brining in a shorter length of time. It was possible to lift the fillets and pack them two days sooner when pure salt brine was used, the control vats being salted with a rock salt brine. Where plant capacity is the bottleneck, the advantages are obvious.

Although Moulton (1929) reports that the presence of common impurities contained in commercial salt does not affect the process of curing meat products, Bellini (1940) presents data supporting his conclusion that calcium and magnesium inhibit the penetration of salt into meat as determined by the chlorine content. Adequate data on the effect of salt impurities in meat processing, however, is lacking in the literature.

The effect of small amounts of calcium, magnesium and sulphates on the development of various types of microbial growth is currently receiving some attention. Hess quotes unpublished data of Gibbons, who observed that a medium containing no calcium or magnesium ions did not support growth of red halophilic bacteria or only very poorly, whereas addition of traces of calcium or magnesium or replacement of the sodium chloride by solar salt resulted in good growth. The same effects can be observed with red halophilic bacteria in the presence of calcium chloride, magnesium chloride, and magnesium sulphate, in high concentrations of sodium chloride. The inhibiting or toxic effect of a monovalent salt like sodium chloride can be neutralized by the addition of a divalent salt in certain amounts as pointed out by Winslow and Falk (1923).

Jensen (1944) points out that beef cured in 100° salometer brine with solar sea salts and stored at 90°-100° F. will spoil with characteristic trimethylamine odors after five months showing a typical flora of Serratia, Achromobacter and Micrococci.

He also points out that in the dry curing process employed to cure country hams and southern style hams, it is sometimes the practice to rub the meat first with sodium nitrate, following by salt and sugar. The nitrate appears to increase the permeability of the meat and Jensen indicates that surprisingly few pieces cured in this way show frank spoilage. He indicates that the effect of nitrate on the permeability to salt has not been given much scientific study. It is interesting to note that the penetration of meat by salt may be hastened by the nitrate ion, while Tressler has shown that calcium, magnesium and sulfate ions retard the rate of salt penetration in fish.

In applying salt to products where rancidity development must be guarded against, it is well to bear in mind that salt may be a source of copper and iron contamination. Cupric compounds in concentrations of 3 to 5 parts per million, and ferric compounds in concentrations of 5 to 10 parts per million are not uncommon. Bear in mind that the salt crystal itself is relatively pure and that the impurities are on the crystal surfaces since they were present in the mother-liquor that was dried onto the surface during the processing. Thus, contact with the fatty portions of foods is to be expected. It has been demonstrated on the plant-scale production level that shelf-life is affected by salt that is contaminated with these heavy metals.

IMPORTANCE OF PHYSICAL PROPERTIES OF SALT IN FOOD PROCESSING

In certain applications of salt, it is possible to make use of the rather wide variation in specific surface of salt products. This idea is being used today to control the consistency of a paste in which salt is one of the major ingredients. It is possible to control the consistency by varying the specific surface of the salt. As the specific surface increases, the product stiffens. Conversely, if it is desired to increase the flow of the paste, this may be done by using salt of lower specific surface.

The number of crystals per pound, which varies over a wide range, is important since it controls the uniformity of salt distribution, particularly in a product like sausage where, because of the high fat content, migration of salt after it dissolves is not easily brought about. By using a salt with a large number of crystals per pound in such a product, it is possible to increase the salt content without increasing the salt flavor. This, we believe, is because the tongue picks out the high points of salty flavor registering the content of salt in locally oversalted areas rather than a true average.

Differences in solubility rate in certain products like butter also control in some measure the apparent saltiness. Carefully controlled experiments have shown that differences in solubility as small as two or three seconds are significant. Although chemical analyses on butter samples in these experiments indicated excellent control of salt content, expert judges of butter in blind sampling tests indicated that samples salted with butter salt dissolving in 9.2 seconds tasted less salty than the control samples salted with butter salt of identical purity but with a dissolving rate of 11.6 seconds. By dissolving more quickly, more uniform distribution of the salt was effected. Uniform distribution of salt in butter is important for another reason besides the flavor. For controlling the growth of organisms that are responsible for development of surface taint, it is important to have some salt dissolved in as many of the minute moisture droplets as possible. Rapid solubility of salt is helpful in bringing this about.

It is possible to make use of differences in density of salt products, particularly to control the fill of packages in those products where salt is one of the important constituents by weight. Variations in density are also significant where salt is

applied by volume as in the salting of soda crackers or potato chips. Variations in density may vary from 2 to 3 percent on the same product to as high as 25 percent, depending on processing control. I should point out, however, that also involved in the application of salt by volume are the flowing properties of salt.

SALT VS. SUGAR AND ACIDS

Fabian and Blum (1943) have studied the relationship between salt, sugars and the common food acids. Their work indicated that the effect of sodium chloride was to reduce the sourness of acids and to increase the sweetness of sugars. The reduction in the sourness of acids was particularly noticeable for lactic, malic and tartaric acids. They also showed that acids increase the saltiness of sodium chloride, except hydrochloric acid, which showed no effect. They showed, too, that all the sugars reduced the saltiness of sodium chloride and also reduced the sourness of acids, particularly lactic, malic and tartaric acids.

Practical applications of the principle pointed out by these workers are of interest. In the curing of meats, salt is the principal ingredient that does the curing, the effect of sugars, nitrate and nitrite being largely confined to the color and flavor. One of the best reasons for adding sugar to a cure for ham or bacon is that it enables us to carry sufficient salt for proper curing without developing a flavor that is too salty. This is an application of the principle that sugar lowers the saltiness of salt.

We have shown that the addition of small quantities of salt, even below the threshold level, will increase the sweetness of sugar solutions. Thus, in a soft drink, the addition of 0.15 percent salt increased the sweetness of the beverage as determined by blind sampling technique. It is interesting that this very small amount of salt—well below the threshold value—caused an increase in sweetness in the case of a particular beverage approximately equivalent to 5 percent of the total sugar in the beverage. In times of shortage, this was equivalent to increasing the total output by 5 percent since sugar was the limiting factor.

When products are very high in sugar, as in the case of soft cream center candies and fondant icings, a small amount of salt appears to cut down on the cloying sweetness. Several experienced candymakers have called this to my attention but I am at a loss to explain the phenomenon.

STORAGE OF SALT

One of the responsibilities of the food technologist should be the supervision of storage of raw ingredients. Therefore, the following suggestions might well be included in this discussion. Salt will pick up off-odors if prevalent in the warehouse. Salt is highly sensitive to variations in relative humidity. The critical humidity range for salt is approximately 70 to 75 percent. When the humidity in the warehouse alternates above and below this level, salt alternately takes up moisture and loses it, the result being a knitting together of the crystals. How firmly the crystals knit together is a function of the contour of the crystals. When granulated salt sets up, it is difficult to rupture the linkages between the particles. Because of irregular contour, it is more simple to rupture the linkages between particles of flake salt that has set up. Salt should be stored in a well-ventilated warehouse, preferably on skids if the floor is of concrete construction and if it tends to be damp. Bear in mind that the humidity increases from floor to floor. The top floor of a building will frequently be much more humid than the lower floors. Therefore, storage of salt on one of the lower floors is recommended. I should also point out that for some reason salt sets up if it comes in contact with a source of heat, such as a radiator, a steampipe, or the side of an oven. Salt should not be stored in contact with

heating surfaces. This is not the sort of caking that takes place due to dampness but it can be just as troublesome.

SUMMARY

1. Use maximum quantities of salt without developing a salty flavor. Remember that salt is a supporting flavor only, with very few exceptions.
2. Make use of differences in the physical and chemical properties of salt, including differences in purity, specific surface, number of crystals per pound, solubility rate and density.
3. Keep in mind the relationship between salt, sugars and acids, and use these principles in controlling flavor.
4. Keep in mind that even distribution of salt is important because the tongue picks up the concentration of salt in locally oversalted areas of a product and does not record the average salt content in all cases.
5. Store salt in a well-ventilated warehouse, keeping the humidity well under 70 percent. Do not store in contact with heating surfaces.

REFERENCES

1. Bellini, B. The effect of salt impurities in processing. Ind. ital. conserve aliment. *15*, 103-7 (1940).
2. Bigelow & Stevenson. National Canners Association Bulletin No. 20-L (1923).
3. Fabian, F. W., and Blum, H. B. Relative taste potency of some basic food constituents and their competitive and compensatory action. Food Research *8*, 179-193 (1943).
4. Hess, Ernest. Effects of various salts on preservation. J. Fish Res. Bd. Can. 6 (1) (1942).
5. Jensen, L. B. Microbiological problems in preservation of meats. Bact. Rev. *8*, 161-188 (1944).
6. Moulton, C. Robert. Meat through the microscope. P-113 (1929).
7. Tressler, D. K. Some considerations concerning the salting of fish. U. S. Bureau of Fisheries Document No. 884 (1920).
8. Winslow, C. E. A., and Falk, I. S. Studies in salt action. J. Bact., *8*, 215-236 (1923).

PROBLEMS IN THE PRODUCTION OF PRECOOKED FROZEN FOODS[1]

BARBARA L. HUTCHINGS AND CLIFFORD F. EVERS
The Birds Eye-Snider Laboratories

In a recent issue of a well-known food magazine, there were written into an advertisement these thoughtful words of a Chinese Christian, "Oh God, give the world common sense, beginning with me." It would be well for every individual interested in the production of precooked frozen foods to keep this maxim in mind.

The problems involved in the production of precooked frozen products are varied and complex. The basic research needed to solve these problems is notable by its absence, causing many capable packers to view the field with skepticism. It is neither these "Doubting Thomases" nor a few of the foolhardy ones already promoting frozen cooked foods without restraint or reservation who will be responsible for establishing the cooked food line of the frozen food industry.

Any successful packer of ready-to-serve frozen foods will have to draw equally from the resources of all departments under his management. Common sense should make production, research and quality control departments cognizant of their own and each other's limitations, and aid them to work in unison to present the buying public with quality products which will meet with repeated consumer acceptance.

PRODUCTION PROBLEMS

One of the earliest approaches to the production of precooked foods was the attempt to use the same processing methods employed in canning, but to package the finished product in a paperboard carton for freezing. This procedure soon brought to light the inherent differences between retort-processed canned foods and ready-to-serve frozen foods.

Canned baked beans were one of the many products curtailed in production by the wartime restrictions of tin cans. To aid the government and to keep up production levels, many processors put up a frozen baked bean pack. The pitfalls encountered in transferring this product from the canned to the frozen production line have left us some very good examples of the typical problems involved in the production of precooked frozen items.

Oven baked beans give a very poor, mushy-textured product when frozen, after receiving the same processing treatment and temperatures as those packed in cans. Cutting the baking time down considerably gives a product of better texture but definitely poorer quality of flavor, and lacking the typical rich brown color associated with the oven baked beans.

The moisture content of the dry beans normally varies from 8 to 13 percent. It was noted that when the moisture content ran between approximately 12 to 13 percent, the beans softened too much in the regular baking time if the regular dilution of syrup with water was used. When the ratio of water to syrup was lowered the baked beans retained their desired texture and color and the flavor of the product was not altered noticeably.

California small white beans, packed in 100-pound bags, were emptied into a hopper which fed into a shaker type screen cleaner. This removed some of the lighter foreign material. As the dry beans fell off the screen, they were subjected to a blower fan which further cleansed them. The raw product was then flumed into a riffle where heavier foreign matter, such as stones or sticks, were separated from

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

the beans. A conveyor belt raised the beans and dropped them on a wide rubber sorting belt where defective beans were removed. This belt emptied the beans into large wooden tubs. Some moisture adhered to the beans from the cleaning process, so they were allowed to stand and drain completely. The beans were never soaked.

A given quantity of syrup was combined with several hundred pounds of cleaned beans in an iron pot. The beans were baked for approximately three hours in a gas-fired brick oven, then the fire was reduced and the dampers closed to develop the color. After five hours from the start of the bake, the beans were stirred, water added to the surface of the beans and the salt pork placed over the beans on perforated trays. The beans were agitated only two or three times during the entire

FIG. 1. Gas-fired ovens for processing New England oven baked beans.

baking process. Usually, water was added only once during the bake. As the beans came from the oven, they were conveyed down a cooling chute where the syrup was diluted. Iron pots of the same type were used to collect the beans and carry them to the packing line. The amount of water added here was in direct proportion to the amount of evaporation during the baking.

Samples taken from the production line described above were held for testing several weeks later. The product gave a good color, and texture, but the flavor was fatty and rancid. Then the pork was tested and it was found to be rancid. Samples of uncooked salt-back pork were tested and found to be nearly rancid before processing—and they were found to be completely rancid shortly after the start of the cook. Various types and qualities of pork were tested. It was found that even pork (barrel pork) of excellent quality became rancid during the bake when baked over the beans. Experimentally, when pork was coarsely ground and mixed with the beans before baking it did not become rancid during the processing or during storage. This procedure was suggested to production and accepted by them. It has been determined that the natural anti-oxidant properties of the beans and/or the molasses accounted for the protection against fat rancidity.

Bacterial counts reported for this product processed under the given conditions were exceptionally high. Examination of equipment indicated that the cooling chutes, the refilled iron pots, and the packing tables might be sources of contamination. By regulating the cooling temperature at the time of packaging and by limiting the holding time before freezing to under sixty minutes as well as the institution of more stringent sanitation throughout the plant, cut the bacterial count down below the level where spoilage through contamination was possible.

These three problems, the maintenance of quality of flavor, texture and appearance, the prevention of rancidity, and the controlling of bacterial counts, could not have been so quickly and successfully solved if production, research and quality control had not cooperated to the best of their ability.

The production problems encountered in the preparation of ready-to-serve frozen foods are to some extent similar to the problems encountered in the canning of a corresponding product. Straight line production will facilitate the most economical use of equipment, labor and raw materials. It will also make it easier for the packers to see and correct any faulty or incorrect procedures. Sanitation is a much simpler problem where equipment is arranged in a straight orderly fashion.

The correct choice of equipment, keeping it to a minimum, will help keep costs low, lessen the danger of accidents, decrease the possibility of contamination and make for more efficient production. In general, it will be more advantageous to put all the ingredients of a batch into one kettle rather than to cook and then combine one or more ingredients for a finished product. In the production of chowders, stews and similar products, this is entirely plausible. The preparation of cakes, pastry doughs and cookies lends itself easily to this one-kettle method. Some specialty items will demand more complex methods of preparation, but all foods should receive as little handling as possible.

The packaging problems facing the production men are acute. Viscous, fatty, rich foods demand special equipment and packaging materials. The standard twelve-ounce frozen food package just won't do. Pies and cakes, pastry doughs and cookies offer a problem in the size and shape of containers. For all of these products which are high in fat content, the packaging materials must be grease-proof as well as vapor-proof. Oxidation and freezer burn are just as great, if not greater, enemies of cooked frozen foods as they have been of fresh frozen items.

There is much to be done in this field and the makers of packaging materials are already developing new materials on the basis of earlier experimentation with cooked foods, but they are waiting for definite specifications of needs to be formulated by the frozen food industry.

RESEARCH PROBLEMS

Nearly fifteen years ago, a great deal of experimental work was carried out on the preparation and freezing of cooked foods. At the time little interest was shown on the part of marketing or production, since the industry was then busy solving the many problems of freezing and distributing fresh fruits and vegetables. Now the picture has changed and there is a great deal of renewed interest in the production of ready-to-serve frozen foods.

Actually, research in this field has not advanced much further than it was fifteen years ago when the Birds Eye Laboratories at Gloucester, Massachusetts, carried out a two year program on the investigation of cooked frozen foods. Today, one phase of research which should receive a great deal of time, effort and expenditure is the field of basic research. There is a great lack of information concerning the naturally occurring physio-chemical reactions of food constituents and the effect

of freezing on these reactions. Some of the developments of off-flavors, off-odors and color changes due to enzymatic and/or oxidative changes in cooked food products are not clearly understood. Many of these changes are thought to be the result of characteristic product variables, including the concentration of components, the loss or gain of moisture or the variable of the individual hydrogen-ion concentration.

Basic research devoted to the complex reactions of the constituents occurring in uncooked foods would give a greater insight into the reactions occurring in cooked foods. Rancidity is a negative reaction of both raw and cooked food products. A great deal has been accomplished through the investigation of anti-oxidants as prohibitive agents. Inherent anti-oxidant properties of natural foods need further investigation, along with the development of more effective chemical and physical methods.

Denaturization of protein is a basic research problem related directly to the field of frozen products, such as lobster, shrimp and crabmeat, as well as many types of cooked frozen foods high in protein content. Retrogression or "staling" of starch needs intensive investigation before the question of the advantages of baked over unbaked frozen products can be answered.

Syneresis is an obstacle in the way of freezing many types of gels or flour-liquid combinations. Here again, the preparation of the product with variables of kinds and amounts of ingredients, temperatures and processing time will not always solve the problem. This problem is based on the colloidal breakdown of reacting components. Research on the colloidal properties of processed foods, as well as the application of already known colloidal properties to the preparation of these products, may help to prevent the problems of curdling and "weeping" of frozen cooked items.

Aside from these very basic research problems, there are many immediate technical problems to be solved in the laboratory, experimental kitchen and the pilot plant.

The function of the experimental kitchen is to develop quality formulas which will freeze successfully, retaining the flavor, color and appearance of freshly-prepared foods for a storage period of at least six months. These home quantity recipes must then be converted into quantity recipes for preparation in the pilot plant in lots of a hundred pounds or more. Only in this way can cooking procedures, times and temperatures be carefully calculated on a production basis. It is here that the practicability and keeping qualities of a product meet the most stringent test. The kitchen should also test the efficiency of packaging materials. Reheating methods, times and reheating temperatures must be carefully experimented with and established for each product in order to give explicit package directions for the consumer. The salability of a cooked frozen product will be in direct proportion to the least amount of time and effort that the housewife will need to spend in reheating the cooked food for table service. The advantages of packaging a cooked food in a unit which may be used for reheating and serving, then disposed of, can be seen by anyone interested in the development of ready-to-serve foods. Through experimental work, the specifications for such a package should originate with the industry.

Storage is one of the most serious aspects of the production of cooked frozen foods. There are exceptionally few products which will retain their "freshness" of flavor and appearance for a twelve-month storage period. Two outstanding exceptions which experimentally have yielded excellent products after twelve months storage are cookie doughs and fruit pies. Most other products will undergo drastic changes in texture, color and often develop a "haylike" or warmed-over flavor. Some of this deterioration can be corrected through the revision of formulas, or the

addition of chemical agents, or through a change in the physical manipulation of the product before freezing. When all of these methods fail, the product becomes a problem for basic research.

During a commercial pack of a cooked frozen product, many of the services which the laboratory could give to production would include the checking of raw material, *e.g.*, the moisture content of cereals, wheat products and legumes, the quality or "freshness" of fats, seasonings and other ingredients. The correction and control of viscosity for sauces, soups and gravies is a technical problem which research may help solve. The utilization of products otherwise considered as waste materials, such as chicken skin, meat scraps, vegetable peelings, and fruit skins, so as to lower the production costs of certain items, is a project that the frozen food laboratories cannot afford to overlook.

Many of the problems relating to the production of precooked foods are of a physical or mechanical nature. This justifies the interest of research in the development or revision of processing equipment. Without encroaching upon the time or functions of production, the laboratory should be open-eyed and open-minded to the mechanical needs of the plant. Utilization of all equipment to better advantage goes right along as a partner to the objective of greater and better production at lower costs.

Poor sanitation is a threat to all commercial packers of ready-to-serve frozen foods. The responsibility for proper sanitation falls upon all three groups, but the greater share of surveillance is the work of the quality control group. However, research may serve quality control by testing the practicability of commercial detergents and cleansers, by instructing quality control personnel in the newest methods of bacterial examination and by check-counting samples when they are questioned by production or management.

QUALITY CONTROL PROBLEMS

Quality products are the results of careful planning, the continuous checking of raw materials, production methods, packaging procedures and freezing techniques. Correctly instituted and adhered to, quality control pays its own way.

Cooked foods for freezing are not sterilized in the same manner as retort-processed canned foods, and since after thawing they may spoil very rapidly if the initial bacterial count is high, it is absolutely essential that plant sanitation be supervised and the sources of contamination be eliminated or held in check. Plant sanitation is a full time job, requiring the services of a trained bacteriologist and technologist. The facilities for packaging may lead to contamination unless all equipment, surroundings, and personnel are maintained at a high level of cleanliness. Cooked foods deteriorate quickly when warm and may even sour or spoil before the freezing process has been completed. This may quite often be the case when the foods are of a heavy, viscous nature.

True control of quality accepts the responsibility for and the regulation of not only plant sanitation but the surveillance of the health and cleanliness of all personnel, selection of top quality raw material and the proper technique in all phases of production.

The hourly, impartial observation and recording of facts is the backbone of an efficient quality control set-up. The method of recording should be made to fit the production problem so that the plant manager, by merely glancing at the report, can see exactly how the day's run is progressing at any given hour.

Quality control should not tag along as the off-shoot of production or research. Its functions are of an importance equal to either department. In order to carry out

an effective program, it should be held accountable only to management, as production and research usually are. Only in this way will quality control be free from the often too-exacting demands of research and the sometimes overly cost-conscious attitude of production.

Common sense, coupled with mutual interest and cooperation between all departments, will set any precooked frozen food company on the right road to success. Of the many products which have been launched upon the market, only twenty or so have remained for any sizeable production. The picture for the future of precooked frozen foods is not a dismal one. The line will be established firmly if products of excellent quality are packed at a reasonable cost to the consumer.

MODERNIZATION OF FOOD PROCESSING THROUGH INSTRUMENTATION [1]

R. E. CLARRIDGE
Taylor Instrument Co., Rochester, N. Y.

Advances in food processing have almost always been accompanied by improvements in machinery and food handling equipment. Quite naturally in the early years the proper instrumentation of a process was given little consideration. This was due to the fact that instrumentation had not made much progress and instrument companies were not in a position to offer material help in the processing industries.

All instrument companies have had a small beginning. Their capital was small, their personnel was meager, and their main assets were an idea and the desire to work. Most of the older companies catering to the process industries entered the field with simple indicating instruments, and these were followed by the more complicated recorder. Eventually the automatic controller was developed and it brought to the instrument companies many problems which did not exist when indicating and recording instruments alone were manufactured. The performance of an automatic controller depends upon the physical characteristics of the controlled process as well as upon the construction and accuracy of the instrument. As a result, every instrument company in the past 20 years has gradually built up a group of application or processing engineers who specialize in the use of control instruments on various processes.

New and improved food processes are normally developed in the laboratory under the able direction of a chemist or food technologist. In many modern laboratories, thousands of dollars are spent each year in an effort to provide new food products and to improve the methods of processing existing products. It is the purpose of this paper to suggest a method for taking a new food or new process from the door of the laboratory to the production line in the plant. Let us first review some of the successful developments in the food processing industry.

Basically the pasteurization of milk is a very simple problem. It is only necessary to heat milk, hold it at a predetermined temperature for a specified length of time, and then chill it reasonably quickly. No difficulty would be encountered in pasteurizing milk in the ordinary kitchen, although it must be admitted that it would be a troublesome chore to the ordinary housewife. In the early days milk was processed in plants in precisely this same way. Even now a great number of the smaller dairies are equipped with holding vats and surface coolers which perform an ordinary kitchen operation on a larger scale. The first instrumentation on this equipment might have consisted of an accurate thermometer and a clock. The full responsibility for time and temperature of the pasteurization was left with the operator. Of course, the instrumentation on the vat was improved, for an operator could not be depended upon to perform his duties satisfactorily day in and day out. The first step was to a simple recorder; but this has been followed by a recording controller.

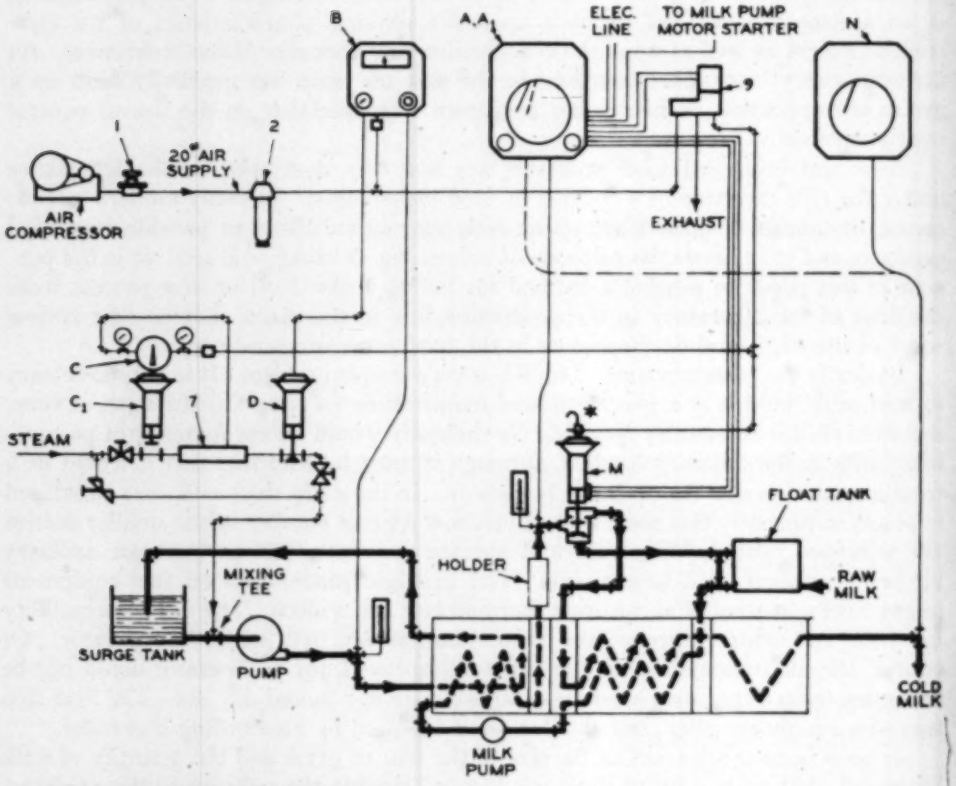
It soon became apparent as the size of the dairies grew and the quantity of milk increased, that quite a bit of time was lost in bringing the milk up to the predetermined temperature in the vat, due to its small heating surface. In order to avoid this time loss, the milk was put through a preheater which brought the milk up to the predetermined temperature prior to its entry into the vat. Almost immediately many problems sprang up, for the controllers which could be used on the holding vats were entirely inadequate for the preheaters. At this point instrument manu-

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 19, 1946.

facturers were consulted and the limitations of existing equipment and instrumentation were emphasized. At that time the problems presented were not simple, for instrument engineers were just beginning to understand those physical characteristics of the process which made its control easy or difficult. For example—time lag, reaction rate, thermal response, water split and other factors of this character were not well defined. Eventually, after quite a bit of experimental work which was not always successful, control systems were developed which were satisfactory for milk preheaters.

Even before the control of the preheater in low temperature pasteurization became commonplace, it was seen that it would be very advantageous if the milk could be heated to a higher temperature for a shorter period of time. It was imme-

TAYLOR TYPE "A" AIR-OPERATED CONTROL SYSTEM
HIGH TEMPERATURE-SHORT-TIME PASTEURIZER
(WITH ACCELERATED HEATING FEATURE ●)



NOTE: SOLENOID VALVE IS SUPPLIED ON MOUNTING BRACKET OF FLOW DIVERSION VALVE. FOR CONVENIENCE THEY ARE SHOWN SEPARATED.

* - OPTIONAL. SUPPLIED AS STANDARD FOR INSTALLATIONS IN NEW YORK CITY AREA.

● - PATENT 2214175

FIG. 1.

diately recognized that this would not be practical if more precise control were not available. From laboratory work it was known that the holding time at the elevated temperature must be measured in seconds. The margin between pasteurized milk and milk with an unsatisfactory cream line in the bottle was extremely small. While degrees were important at the lower holding temperature, fractions of a degree were equally important at the higher temperature. Therefore, it was recognized that this improvement in processing could only be accomplished by cooperation between the machinery and the instrument manufacturer. The combination was fruitful, for "short time" pasteurization has become a reality and is growing in popularity.

The basic control system for the typical short-time pasteurizer is illustrated in Fig. 1. Raw milk is fed through a small tank to a preheating or regenerative section of a heat exchanger. The pump picks up the milk and passes it in heat exchange with water being rapidly circulated by a centrifugal pump. The temperature of this circulating water is accurately controlled by an instrument and a valve installed in the steam line to an ejector. From this section of the heater the milk passes through a holding tube which is of a suitable length and size to maintain the milk at the desired temperature for the desired length of time. The milk then goes through a diversion valve, to the regenerative section of the heater, where it gives up a part of its heat to the raw milk. It then enters a cooling section and finally is directed to the filler. A positive displacement pump is used to push the milk through the heat exchanger so that the milk flow will be substantially constant. A pressure controller regulates the steam supply to remove steam pressure variations. The water is circulated by the centrifugal pump at a high velocity to increase the heat transfer between the water and the milk, and to keep the "split" between the water and the milk at a minimum value. All of these refinements are essential in order to obtain control within the desired degree of accuracy.

As a safeguard, a safety thermal limit controller and a flow diversion valve have been added to the circuit so that if the temperature of the milk leaving the holder falls appreciably, the milk will be diverted back to the supply tank, thereby preventing any unpasteurized milk from reaching the filler. The instrument engineer contributed materially to this process improvement for the safety thermal limit controller and the flow diversion valve were developed exclusively for this application. In addition, his earlier studies on the low temperature preheater emphasized the necessity for eliminating all possible load changes. Note the steam pressure controller and the constant displacement milk pump. For this type of heater the high velocity water circulation with the small water split was also shown to be beneficial.

Figs. 2, 3, 4, and 5 illustrate several different types of plate heater installations which utilize the control system schematically illustrated in Fig. 1. Fig. 6 shows a tubular heater which performs essentially the same function, although in this case the milk is heated directly by low pressure steam.

The point to this story can be briefly summarized. The process is successful commercially due to the cooperation of three groups of individuals. First, there is the chemist or food technologist who developed and improved the process. Second, there is the machinery manufacturer who developed the equipment to perform the process on a commercial scale so that it will be profitable to the dairy. Third, there is the instrument engineer who must analyze the process and develop satisfactory instruments to make the installation as automatic and as fool-proof as possible.

Another process which was developed is the steam peeler illustrated in Fig. 7. In this peeler, potatoes or some other similar vegetable are loaded into a drum which

FIG. 2. Plate heater installation No. 1, equipped with control system.

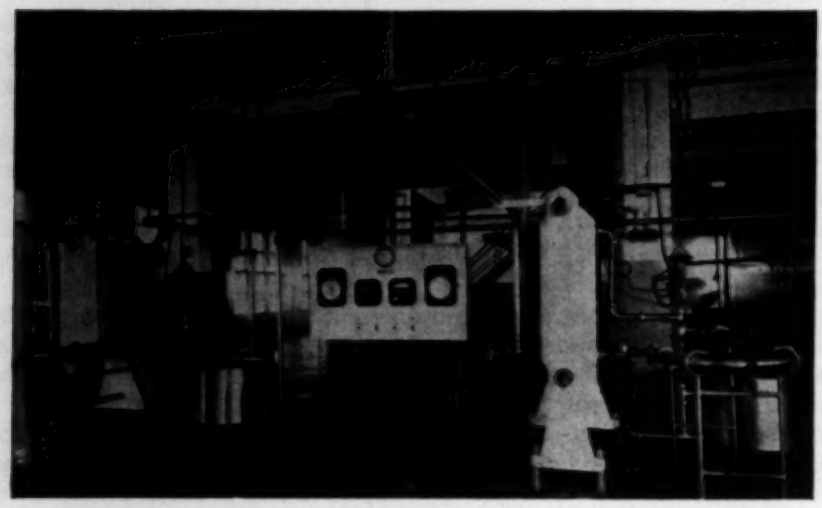


FIG. 3. Plate heater installation No. 2, equipped with control system.

FIG. 4. Plate heater installation No. 3, equipped with control system.

FIG. 5. Plate heater installation No. 4, equipped with control system.

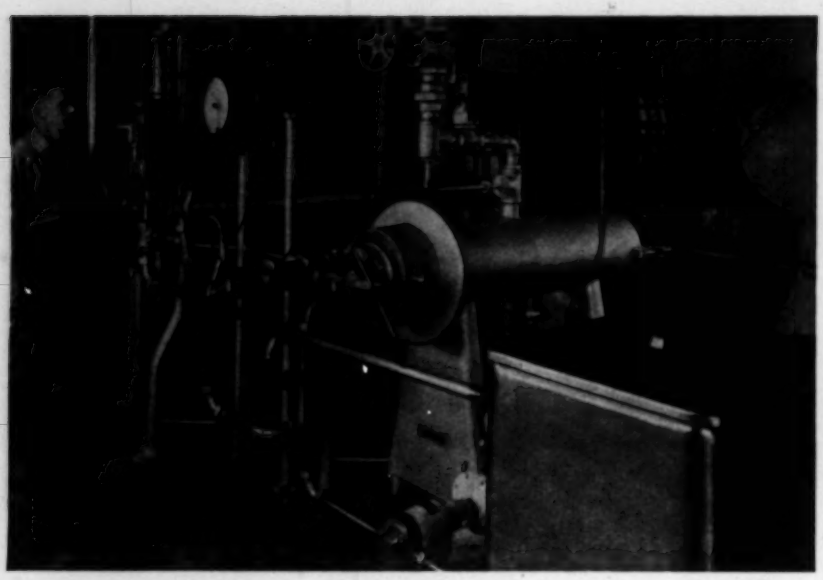


FIG. 6. Tubular heater installation, equipped with control system.

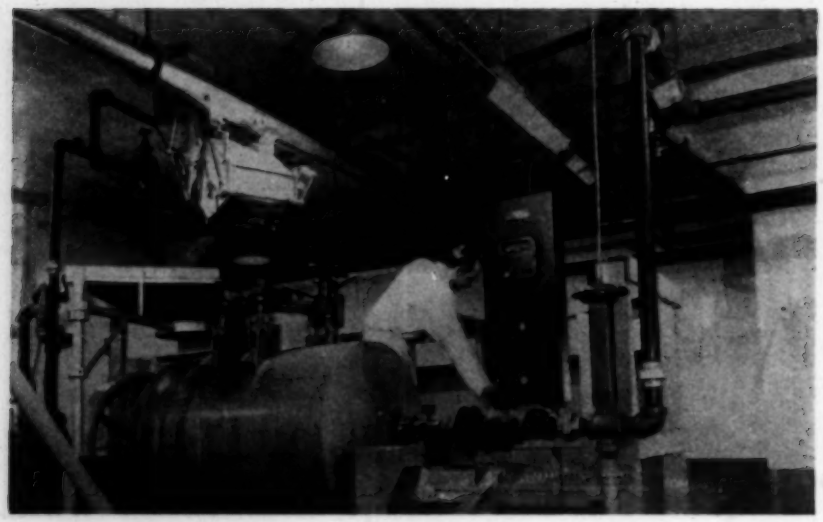


FIG. 7. Steam peeler, equipped with control system.

is subsequently revolved and high pressure steam is admitted into the drum for a predetermined length of time. It is doubtful if this process would be commercially successful if it were not for the automatic control system. In this photograph the top instrument on the panel board controls the steam pressure while the lower instrument controls the time of the process. The valve operated by the Flex-O-Timr is rather unusual in the food processing industries since it admits steam to the drum during the process and vents the steam from the drum at its termination. A valve of this type is called a three-way valve. The valve operated by the pressure controller is not visible.

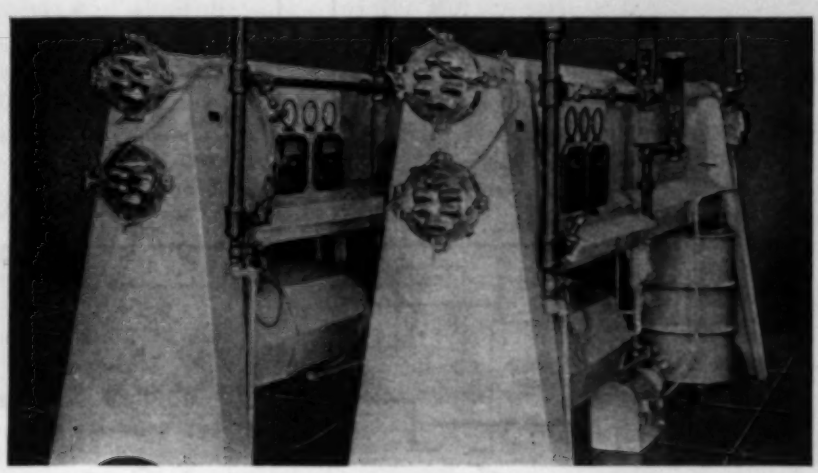


FIG. 8. Tubular juice heater with control to prevent burn-on.

Fig. 8 illustrates a tubular type juice heater which uses steam below atmospheric pressure. The main problem presented to the instrument engineer by the machinery manufacturer when this unit was developed was the prevention of burn-on in the heater when the flow through the heater was suddenly stopped. This problem was solved by utilizing a sensitive bulb eccentrically located within the tubes of the heater. It is unfortunate that all the problems of the instrument engineer are not this simple.

Fig. 9 is interesting because it presents the variations in the piping and instrumentation on a plate heater when it is used for high temperature flash pasteurization of juice. In this case the raw juice entering the heater is divided, part of it passing through a preheating section. The purpose of this section is to heat a part of the raw juice and to cool the pasteurized juice to the desired filling temperature. In order to control the finished juice temperature, an instrument with its bulb in the juice outlet operates a valve in the raw juice bypass line around the regenerative section. This same instrument is equipped with two extra thermal systems which record the raw juice temperature and the temperature of the juice leaving the holding tube. A second controller has its bulb located in the juice entering the holding tube, and operates a valve in the steam line to the circulating water system. The function of this instrument is to make sure that all juice entering the holding tube has reached the desired pasteurizing temperature. The second tube system in this instrument records the circulating water temperature. A rise in the water temperature usually indicates that the plates are fouled and need cleaning. The third instrument has the simple function of recording the temperature in the filler. A quick comparison of Fig. 9 with Fig. 1 illustrates how changes in processing

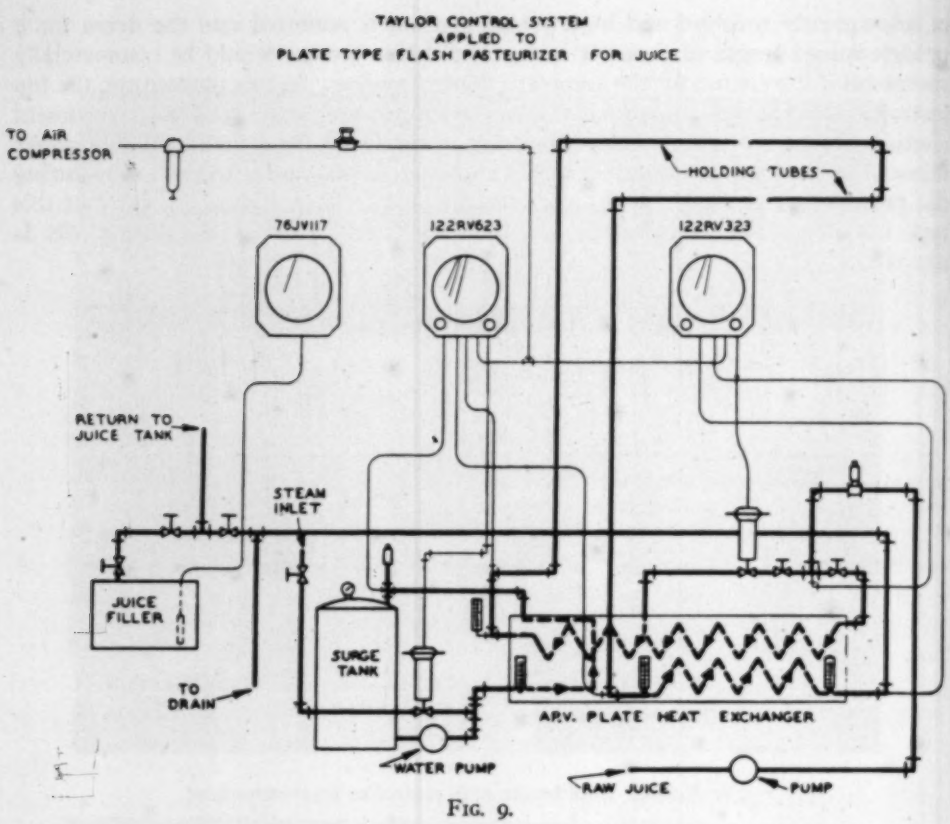


FIG. 9.

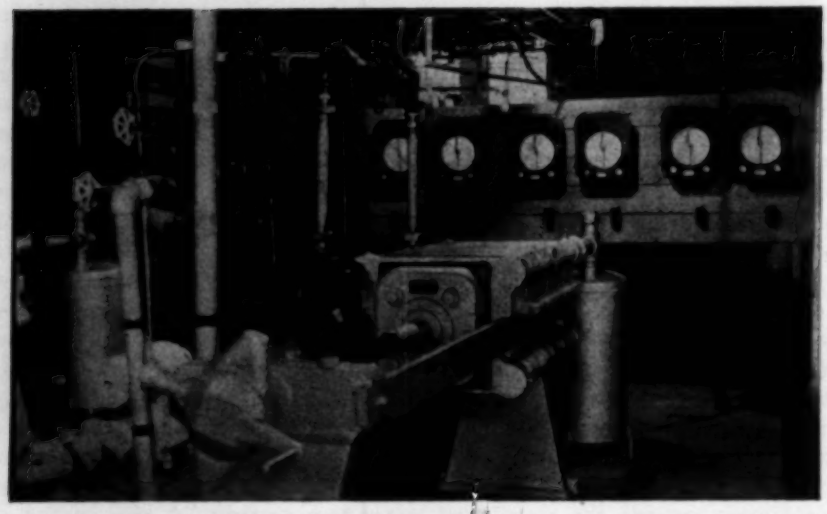


FIG. 10. Two-stage evaporator, equipped with density controller.

requirements on a simple plate heater can cause major instrument variations. Fig. 10 is a photograph of an installation in a typical juice plant.

A two-stage evaporator shown in Fig. 11 has been used very successfully in preparing tomato paste for catsup and other similar products. Evaporators of this type have been in use for a number of years, but it has always been necessary to provide skilled help for their operation. Several years ago through a cooperative development program this control system was worked out for evaporators. The vital item in this particular hook-up is the density controller, and it is interesting to note that this instrument would be entirely inadequate if it were not for the level controllers, the steam pressure controller and the vacuum controller which materially reduce the load changes on the density instrument.

Drum dryers are used in the preparation of cereals, high protein cattle feed from distillery slop, and in other branches of the food industry. Fig. 12 is a simple schematic diagram of a drum dryer. Due to the high percentage of solids in the material being dried, level control on drum dryers has never been satisfactory. The successful solution of the evaporator control problem brought an opportunity to work on this level problem, and resulted in the instrumentation shown in Fig. 13. The instrument has a short range and is sensitive to low pressure variations. A small quantity of air is bubbled into the material, its back pressure being determined by the height of the material above the end of the bubbling tube. The instrument responds to this back pressure and controls a valve feeding the material to the space between the drums. On the initial installation, as each bubble broke away from the end of the bubbling tube, a pulsation was produced on the instrument. It was necessary to damp out these pulsations and the double orifice was found to be most effective. It was also found that the material tended to cake and build up on the end of the bubbling tube; and in order to avoid this, a small amount of water was admitted continuously to the tube, thereby keeping it clean. These are developments that an instrument engineer can logically be expected to contribute toward an improvement in a food processing problem.

In the manufacture of carbonated beverages it has been customary through the years to control the carbonator manually. The carbonator is a device in which carbon dioxide under pressure is added to chilled water prior to the addition of syrup. In the preparation of carbonated beverages, quite a bit of work has been done in the laboratory to determine the correct carbonation for a given beverage. This is considered almost as important as the composition of the syrup. When too little carbon dioxide is present in a beverage it tastes flat and loses consumer appeal. When too much carbon dioxide is present the pressure in the bottle is excessive, particularly when it is inadequately chilled. Most of us have had a bottle opening experience in which the effervescence of the fluid produced a considerable spill. This is due to an excess of carbon dioxide or an inadequate chilling of the bottle.

The control system illustrated in Fig. 14 was developed to produce automatically the correct degree of carbonation of the water used in the preparation of soft drinks. The controller itself is a ratio controller which measures the temperature of the chilled water and adjusts the pressure in the saturator or carbonator in proportion to this temperature. As the temperature of the chilled water rises, the pressure in the saturator is increased so that the carbonation remains substantially constant. It is interesting to note that the ratio controller used for this application was borrowed from the air conditioning industry by the instrument engineer. It was originally developed to adjust the temperature inside a theater or auditorium in accordance with outside temperatures so that the audience would not experience "thermal

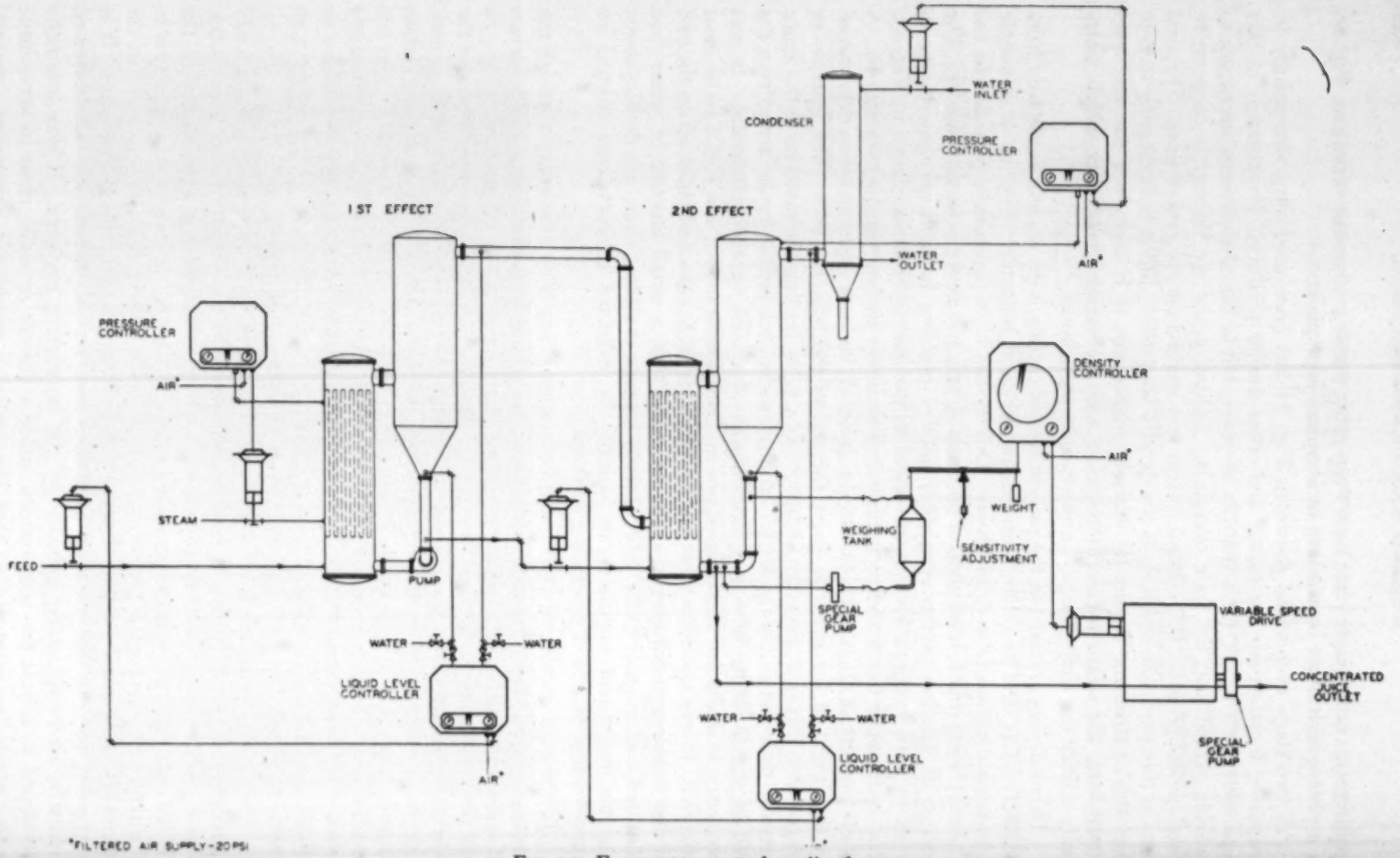


FIG. 11. Evaporator control application.

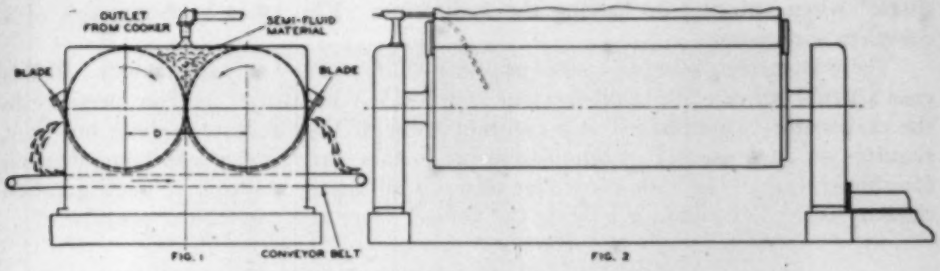


FIG. 12. Schematic diagram of a drum dryer.

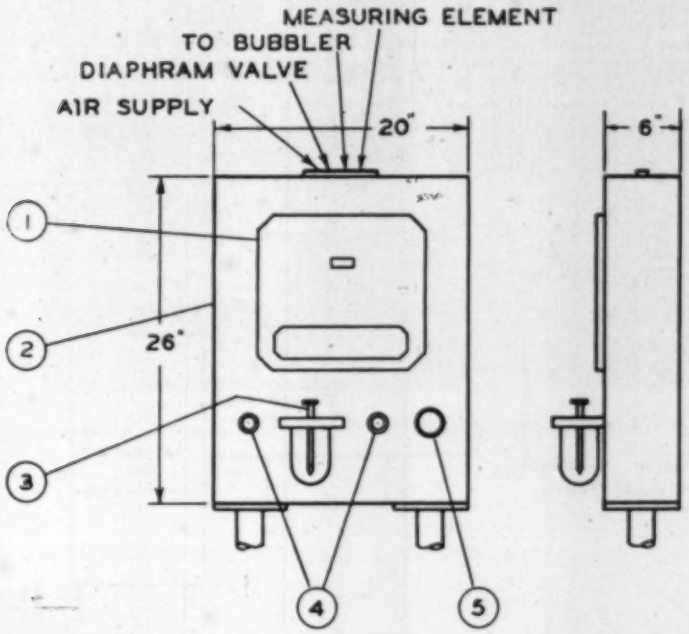


FIG. 11. Evaporator control application.

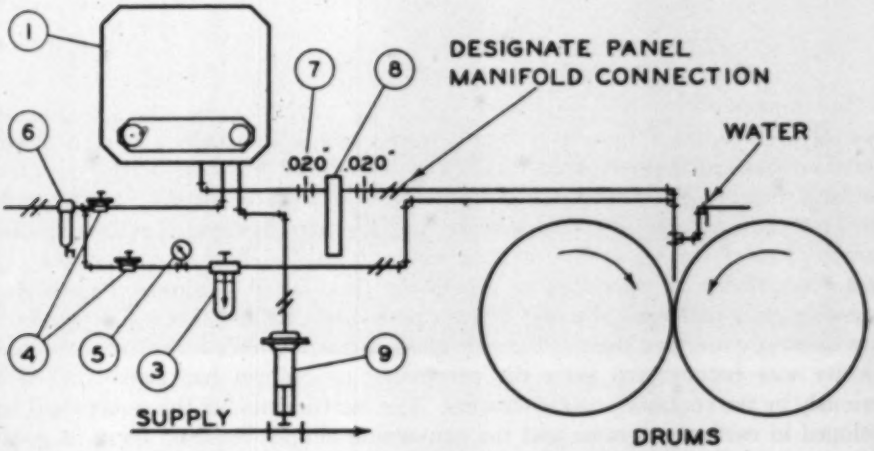


FIG. 13. Schematic diagram for drum dryer control panel.

shock" when entering or leaving the auditorium. Fig. 15 is a photograph of a complete carbonator.

There is another solution to this problem which is also very satisfactory. In this case a temperature of the chilled water is accurately controlled and the pressure in the carbonator is maintained at a constant value. This alternate system, however, requires an adequate refrigeration capacity to take care of the maximum demand for chilled water. The ratio controller set-up is advantageous when the refrigeration capacity is not adequate for holding the chilled water at a constant temperature.

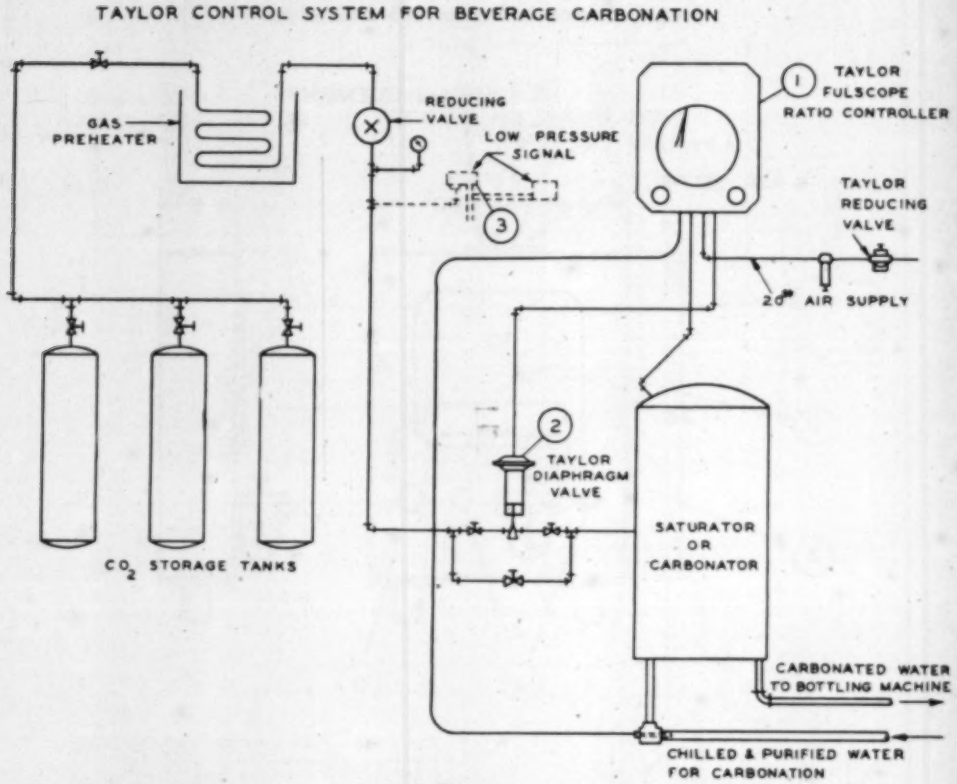


FIG. 14.

The canners retort has been used with little variation for years in the food processing industries. There have been few changes in the retort although recently several mechanical improvements have been introduced by some of the machinery manufacturers. In the East most canners use two or three basket vertical retorts while on the west coast and in the meat packing industry, horizontal retorts are more common. Retorts have been and in some cases still are under manual control. This is not too difficult an operation in processing tins, but it is almost impossible in processing glass packages. During the war period when there was a shortage of tin, many canners converted their retorts for glass packaging and, fortunately, no major difficulty was encountered since the processing procedures had been worked out previously by the container manufacturers. The instruments for the retorts had been developed in earlier programs and the conversion simply required them in greater numbers. A typical modern retort room is shown in Fig. 16.

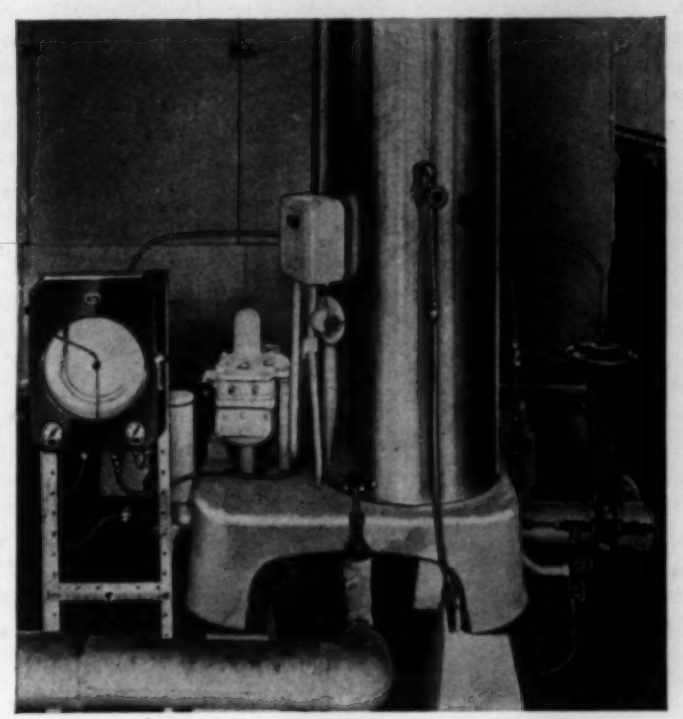


FIG. 15. Carbonator, equipped with controller of ratio between temperature and pressure.

FIG. 16. A modern retort room, showing instrument panel.

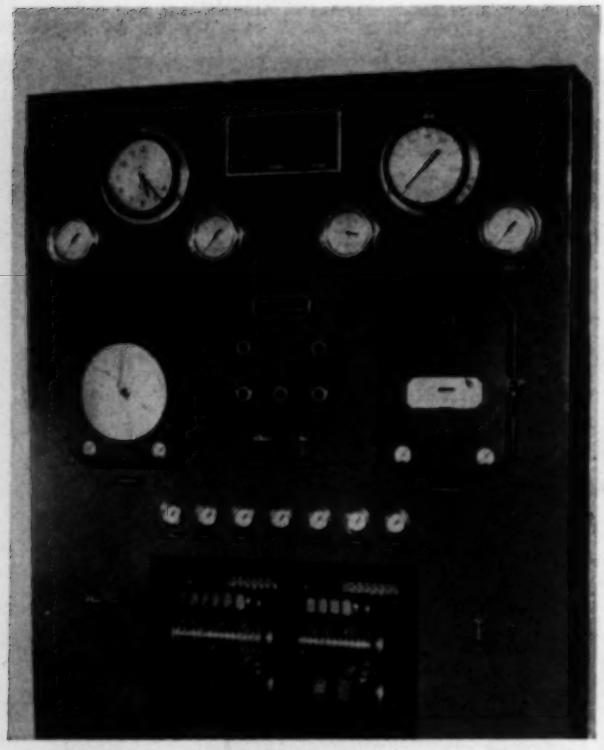


FIG. 17. Instruments for a process of tempering tobacco.

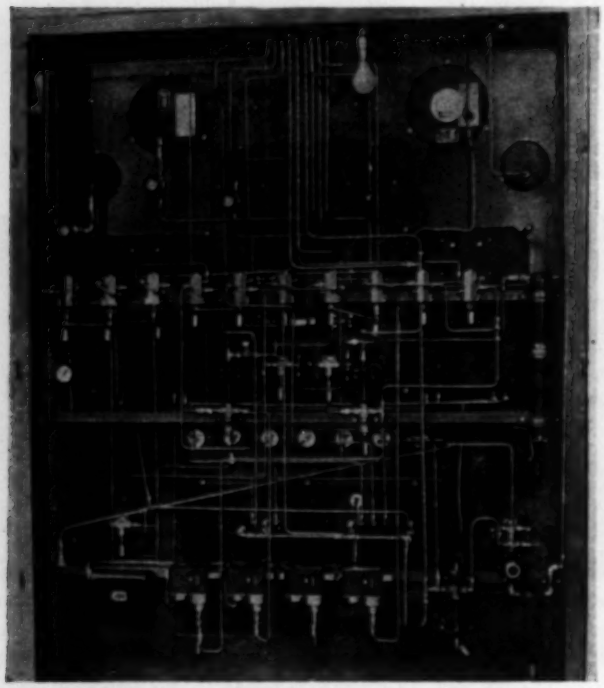


FIG. 18. Back of panel shown in Fig. 17.

An extension of this development program is now in progress, for the advantages of automatic control with inadequate and inexperienced manpower were very great. It is to be expected that within a few years a retort operator will be required only to push a button after loading the retort. The control system will carry on from this point, controlling the temperature, timing the cook, and timing the cool. At least one installation has been made, which performs all of these functions at the present time, but it must be regarded as experimental.

Fig. 17 illustrates the indicating and controlling instruments which are necessary in a new process which has been developed for tempering tobacco and grain. Of course, the valves which control the evacuating and steaming equipment are mounted on the tempering chambers and are operated by the instruments on this panel. In general, these tempering procedures call for the production of a relatively high vacuum followed by successive steamings to introduce the desired amount of moisture into the product prior to its further processing. In the tobacco conditioning field, this process requires from one to two hours while the older steaming operation which it replaces required from one to two weeks. In addition, the product is more uniform when it is conditioned by the new process. This process and instrumentation again was worked out through the cooperation of the equipment manufacturer and an instrument engineer and the process is set up so that after the initial operation of the push button, the entire operation is automatically controlled. An interlocking system is used on this hook-up which makes sure each operation occurs in sequence. In addition, it provides safeguards to prevent dangerous manual interference with the operation. This control system is purchased as a complete unit and is tested thoroughly before it is shipped from the factory. A better idea of the complicated nature of the hook-up and the interlocks which are provided are better illustrated by the back of the panel, Fig. 18.

From this rather brief review of a few of the processes in the food industry, it may be seen that one common denominator for success is cooperation. It is not argued that one can take a process which is not economically sound and by proper machinery and instrumentation create a commercial success. On the other hand, the assistance of the machinery manufacturer and the instrument engineer can certainly be helpful in carrying the process from the laboratory to full-scale operation.

SIMPLIFIED MODERN METHODS OF CONVEYING, BRINING, WASHING, SYRUPING AND PRECOOLING COMMODITIES FOR FREEZING AND PRESERVING[1]

MICHEL P. VUCASSOVICH
Gorton-Pew Fisheries Company, Ltd., Gloucester, Mass.

There are many well known methods of brining or pickling foods. Some of these methods are continuous and some are intermittent. The methods used are by direct sprinkling of salt, by immersion, and by spraying, but the one most commonly used is brining by conveying the food products through the brine with the aid of a single or double belt. All these methods accomplish more or less satisfactory results, but in the course of their operation one encounters many defects.

The apparatus which I have developed and which I am going to describe today with the help of a few illustrations, is a method that does away entirely with belts or other mechanical devices in the direct procedure of conveying and brining different kinds of fish, fish fillets, shrimp, pickles, berries, fruits, etc. The only conveyor mechanism that is required is one for removing these products out of the tank and delivering them where they are to be packed. This apparatus can be used for washing these commodities as well as brining them and, in the case of berries, to syrup them, before freezing.

The novelty of this method and apparatus is to simultaneously clean, chill and brine or sweeten by taking advantage of fluming with a brine solution, or liquid sugar syrup. After the products are brined or syruped, they are elevated by a mechanical device with which this apparatus is equipped at its extreme end, and placed thereby on a weighing or packing table.

By this process the commodities are washed in brine in order to add a small increment of salt as well as to remove objectionable adherent matter which may be present. This method is applicable to many kinds of foods such as fish, fish fillets, shrimp, also mollusks such as oysters, clam, and scallops when removed from their shells, the flesh of other shellfish, pieces of meat and vegetables, berries and, in general, all foodstuffs preparatory to freezing for preservation.

In this apparatus the commodities are tumbled in brine and conveyed from the brine to the weighing or packing table. In describing this method I will make reference through this paper, for convenience sake, to the rosefish fillets, as a step in a continuous procedure of cutting fillets from the whole fish, and inspecting, washing, brining, packing and freezing the fillets.

The fillets are cut from the whole fish and are then brought to the inspection and brining table. This table is combined with flumes of brine at opposite sides. The operator places the fillets into this flume through which brine is caused to flow and from which the brine emerges into a tank. By this combination the brine issuing from the flume causes a turbulence and flows towards the elevator.

The flumes (Fig. 1) extend horizontally close beside and slightly below the candling tables. They are substantially horizontal with possibly a downward inclination throughout the length of space where the inspectors are stationed. The flumes may be open at the top throughout their length or may be covered, with open spaces only at the operators' stations.

The candling tables are close beside the conveyor which brings the fillets, and the flumes are close beside the candling tables in locations convenient for the

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

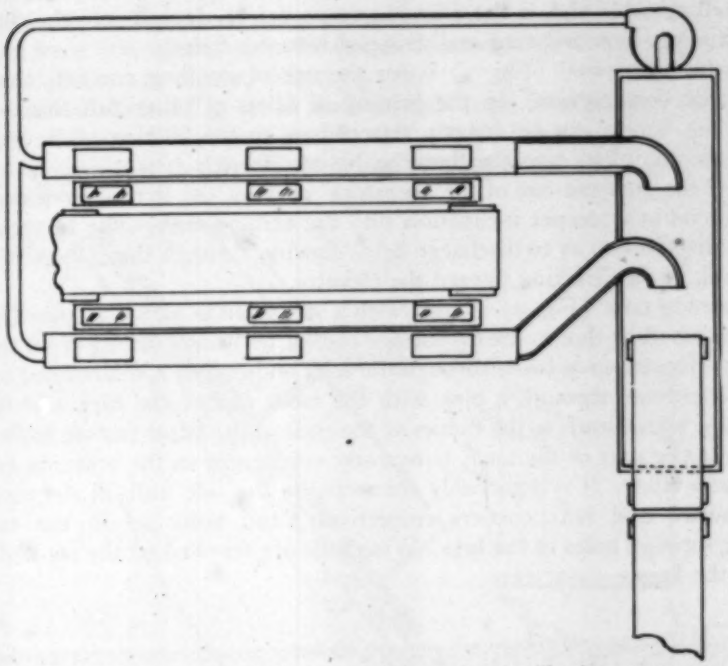


FIG. 1. Diagrammatic plan view of the entire combined apparatus.

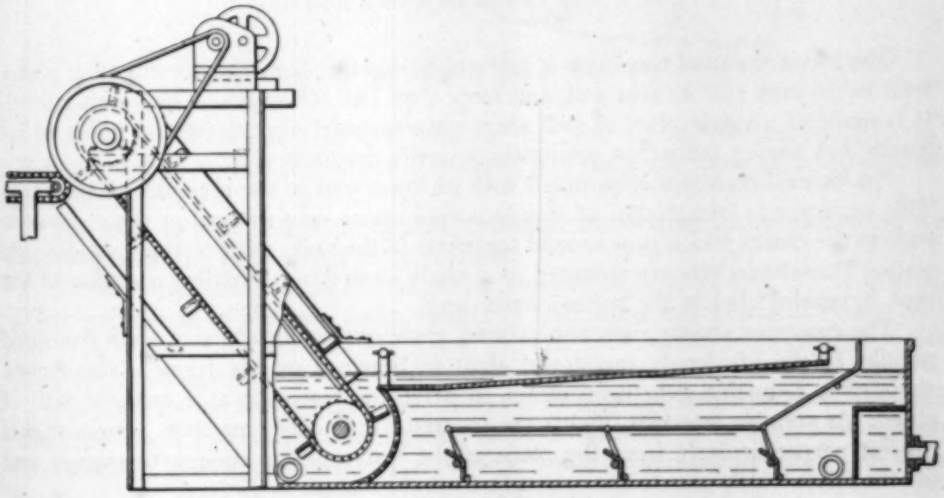


FIG. 2. Side elevation of the apparatus.

operators to reach over the conveyor, pick up a fillet, lay it on the translucent pane of the candling table and, if the fillet shows no defect, drop it into the flume. If it needs trimming, it is trimmed and dropped into the flume.

The table illustrated (Fig. 1) is for the use of candling rosefish, therefore its characteristic construction. In the brining of fillets of other fish that require no candling, the flumes can be directly attached on to the filleting table whereby the filleter drops the fillets into the flume as he cuts them.

Beyond the endmost one of the operators' stations, the flumes have end sections which descend at a steeper inclination into the brining tank. The terminals of the flume are disposed so as to discharge brine flowing through them lengthwise of the brining tank in the direction toward the elevator.

The brining tank (Fig. 2) is filled with a salt solution as full as possible without causing an overflow due to the turbulence caused by brine pouring from the flumes. A constant circulation of brine through the tank and flumes is maintained by a pump which is connected through a pipe with the front end of the tank and discharges into the pipe which leads to the flumes at the ends of the latter remote from the tank.

In the upper part of the tank, but mostly submerged in the brine, is an inclined deck or baffle plate. It is detachably connected to the side walls of the tank by lugs at its forward and rear corners respectively, and bolts set in the tank walls projecting through holes in the lugs. Wing nuts are screwed on the ends of the bolts to retain the lugs.

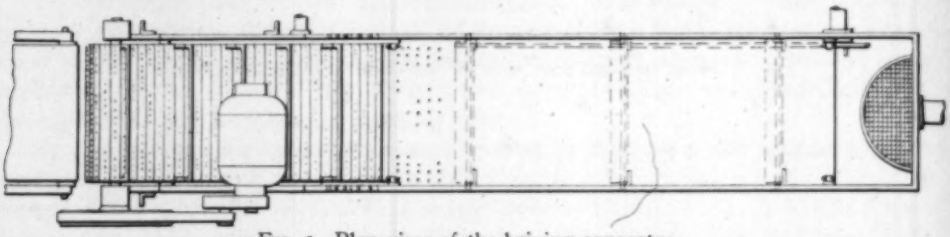


FIG. 3. Plan view of the brining apparatus.

The forward end of this ramp is preferably slightly above the normal quiet water level in the tank and its rear end, and more than half its length, is below that level. It is made of a single plate of stiff sheet stainless steel imperforate for most of its length, but having numerous perforations in the rearmost part.

An inclined conveyor is mounted with its lower end in the rear part of the tank. This conveyor is constructed of stainless steel metal slats secured at their opposite ends to the chains which pass around sprockets in the tank, close to the opposite side walls. These sprockets are mounted on a shaft located horizontally crosswise of the tank in bearings below the normal water level.

The conveyor chains pass also around sprockets on an elevated shaft mounted parallel to the previously mentioned shaft in bearings on the frame. This frame supports a reduction gear-head motor to drive the conveyor at a suitable rate of speed. At suitable intervals, flights are secured to the conveyor slats. These flights project perpendicularly from the plane of the conveyor far enough to engage and lift the fillets which pass to the conveyor from the ramp.

The flight (Fig. 3) is made of a plate of stainless steel metal having a base flange equal in width to one of the slats. The flights and slats are perforated to permit escape of brine lifted with the fillets.

The edges of the flights, as well as the slats, are so fitted to the edges of the

tank as to prevent any fish pieces from falling away from the edges of the conveyor and the ends of the flights and being jammed thereby against the walls of the tank.

The forward end of this elevator can be located to discharge onto a weighing table or extended to any desired delivery point.

A perforated shield (Fig. 4) or wall extends from the rear end of the ramp to the bottom of the tank and occupies the full width of the tank. It is cylindrically curved to be coaxial with the idle shaft, and is close to the orbit of the outer edges of the flights.

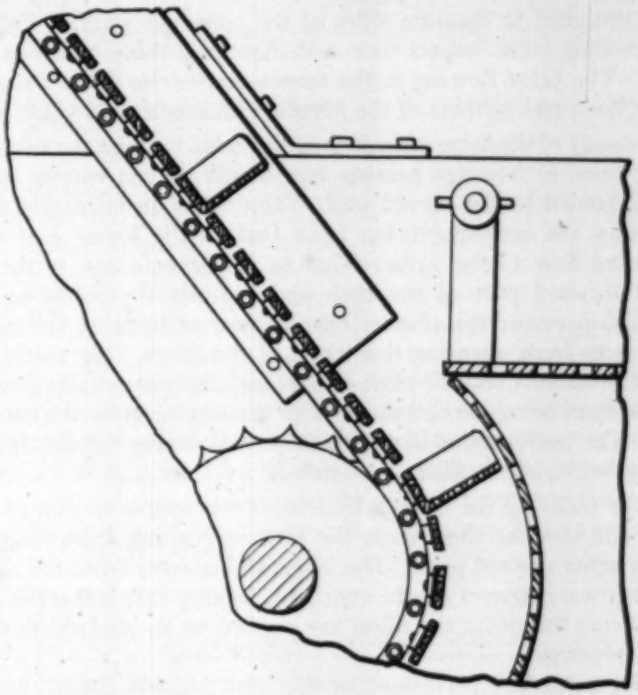


FIG. 4. Sectional view showing details appearing in Fig. 2.

A strainer is mounted at the front of the tank around the entrance to the eduction pipe so that all the brine which flows into the pump must pass through the strainer.

The tank is provided with suitable drains at the bottom for withdrawing the contents when the brine needs to be changed.

Baffles are mounted in the bottom of the tank extending from side to side thereof. Their purpose is to obstruct scales, debris of fish, slime and sediment of any sort which is washed from the fish fillets, and prevent such matter from passing to the strainer and clogging it.

They are connected to pivot rods mounted in bearings in the sides of the tank and their lower extremities abut against stops so disposed as to hold them against displacement by the pressure of the flowing brine, in vertical position with their bottom edges, close to the tank bottom. They may be swung away from the tank bottom to permit washing away of the collected sediment when the brine is changed.

Suitable means for removing these baffles is provided, including a rod extending through the space between the front wall of the tank and the forward edge of the ramp to connect with an arm rising from each of the baffles.

In the use of the apparatus the tank is charged with sodium chloride brine having whatever proportional content of salt required for a prescribed flavoring effect.

When the foods treated are to be frozen, the lower section of the tank can be fitted with a refrigerating coil or ice is put in it and replenished as it melts. This chills the brine and thereby the fillets placed in it, to a temperature at or near the freezing point of water, say from about 32° F. to about 35° F. The brine is then constantly circulated through the flumes and tank by the pump and connections described.

Operators stationed at opposite sides of the conveyor remove the fillets, place them on the candling table, inspect them and then drop those which pass inspection into the flume. The brine flowing in the flumes carries the fillets along and passes through the inclined end sections of the flumes with accelerated velocity.

The high velocity of the brine emerging on the ramp tumbles the fillets vigorously, thereby giving them a thorough brining and washing, then carries them into the annular space bounded by the curved wall. The deck is an important factor in this action. It divides the incoming brine from that in the lower part of the tank, causing a reversal flow of the brine. That is, it prevents any of the fillets from sinking in the forward part of the tank and compels the fillets to pass to the conveyor. It also prevents the counter current flow of brine to the outlet connection with the pump from opposing this travel of the fillets. The shield or wall is a cooperating factor in this respect since it prevents the pieces falling from the rear end of the deck from being carried away from the conveyor by the counter current flow of brine. The perforations in this wall permit passage of the brine with but little obstruction while all the fillets are retained.

The conveyor picks up the fillets which enter this space, as well as those which pass across it, and elevates them from the tank, depositing them on the weighing platform or any other desired place. The brine drains away from the fillets through the numerous holes and spaces on the conveyor, leaving only adherent film of brine on the fillets. From this point the fillets are carried on to the further final steps of packaging and freezing.

In the brining procedure performed by this apparatus the fillets are well washed and all loose scales and slime which may have been on them previously are removed.

They are also cooled to a low temperature, which facilitates subsequent freezing. From time to time the apparatus is emptied and filled with new brine. The frequency with which the brine needs to be changed depends on the thoroughness with which the fish have been previously washed and the quantity of fish being passed through the procedure in a given time. In our case, we change it every two hours. The strength of the brine is also built up from time to time.

The fact that fillets placed in the parts of the flumes remote from the tank are immersed in the brine longer than those placed in the flume at points nearer to the tank makes no material difference in the amount of salt which is absorbed by the fillets. Laboratory tests have proved that the absorption is almost the same whether the fillets are left in brine for five seconds or thirty seconds, provided the concentration of salt in the brine is the same, but more salt is taken up from stronger than from weaker brine.

The following table gives the results of tests of twelve samples, of which six were immersed for different lengths of time in 40 percent brine, five were immersed in 15 percent brine, and one was analyzed without immersion.

In the usual commercial practice brine from 12 to 14 percent concentration of salt is used.

The foregoing description (Table 1) of one phase and utility of the apparatus is not to be taken as limiting to a combination which includes flumes or in respect to the food articles which may be treated with the apparatus.

TABLE 1

Table of Salt Absorption of Various Time Lengths and Brine Concentrations of Fillets

Brine concentration	Sample No.	Seconds in brine	Salt content percent
40%	1	5	0.97
40%	2	10	1.00
40%	3	15	0.97
40%	4	20	1.00
40%	5	25	1.10
40%	6	30	1.10
No brine	7	....	0.58
15%	8	5	0.76
15%	9	10	0.62
15%	10	15	0.67
15%	11	20	0.72
15%	12	25	0.71

The brine may be continuously (Fig. 5) delivered into the tank by other means while being continuously withdrawn and circulated. This figure illustrates a modification in which brine withdrawn from the tank by the pump is returned thereto through pipes 1 and 2, the former of which discharges a stream lengthwise of the tank from the front end over the deck and the other extends lengthwise over the deck and is fitted with a series of nozzles through which many sprays are discharged.

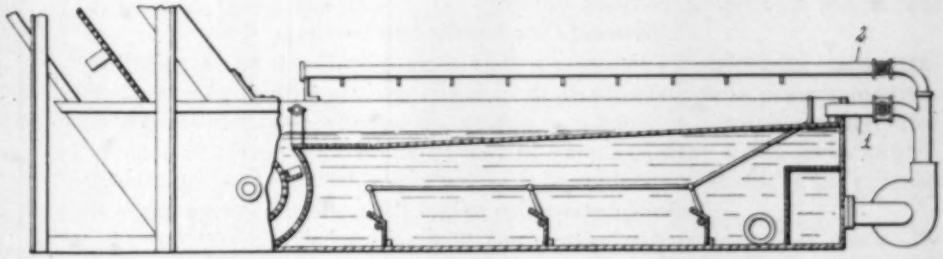


FIG. 5. Modifications in which brine withdrawn from the tank by pump is returned thereto through pipes 1 and 2.

Both pipes are connected with the outlet of the pump and individual valves are provided whereby either may be put into use exclusively or both simultaneously. The pieces of foodstuffs may be placed on the deck by being dumped from containers or delivered by a conveyor or otherwise. The constant withdrawal of brine from below the deck and constant admission through either or both pipes above it, aided by the slope of the deck, causes travel of the food pieces to the conveyor.

The deck is here shown as extending all the way to the front end wall of the tank, thus illustrating that the deck may cover any desired portion of the length of the tank between the conveyor and the end from which the brine is withdrawn.

Here the operating rod for the baffles passes through a slot in the deck. In other respects, the tank and its accessories are the same.

Split whole fish, fillets, oysters, clams, shrimps, lobster meat, the meat of animals, various kinds of vegetables, fruits, berries and, in short, all foodstuffs which may be benefited by washing, brining or syruping as a step in their preparation for the market, can be treated in this apparatus. Such food pieces as do not need inspection with the aid of transmitted light, or which have been previously inspected, can be dumped directly into the tank as shown in Fig. 6; while in the cases where inspection to detect the presence of parasites, blood clots, bruises, or other defects is carried on as part of a continuous procedure, the apparatus employing candling tables and flumes is used. Also any of the food articles herein contemplated may be placed in a flume and conveyed by a stream of brine therein to the tank.

TRANSPORTATION OF FRESH FRUITS AND VEGETABLES[1]

D. F. FISHER
U. S. D. A., Washington, D. C.

I presume that any special interest in the transportation of fresh fruits and vegetables is in them as raw material for manufacturing purposes. Yet all of you must be interested in them also as consumers. But whether intended for use in manufacturing or in your own home, you should be interested in maintaining them in good condition and with high quality until you are ready to use them.

It is my purpose to point out how this can be done best when they have to be shipped long distances. This must be done with many products, particularly for the fresh produce trade. But it is likewise done with many items of fresh produce used for manufacturing purposes, although in general, food processing plants are located close to their main sources of supply. However, this is not always true for all items used by such plants, and often shipments are received from distant producing areas. They are shipped long distances because, for the most part, major producing areas are located where soil and climate are most favorable for particular crops, regardless of distance from terminal markets. Great agricultural enterprises thus have grown up and now flourish in remote parts of the country. This comes about as a result of fast dependable transportation and the development of adequate methods of handling, packing, and shipping perishable produce. It has given rise to highly specialized businesses in the production and marketing of crops upon which many processors depend and from which come seasonally most of our fresh market supplies.

Time will not permit consideration of all the factors that affect the successful long-distance shipment of fresh fruits and vegetables. Accordingly, we will consider it as axiomatic that they must be harvested at the proper stage of maturity, be free from disease and insect infestation, be carefully handled to prevent mechanical injury, and be properly prepared and packed for shipment.

Let us then take up the discussion of what is required for successful transportation from the time of loading in order to get fresh produce to you in prime condition. The principles are the same whether the vehicle be a truck or a railroad refrigerator car, but since most of our work in the Bureau of Plant Industry, Soils, and Agricultural Engineering has been with the latter, let it be understood that it is the railroad refrigerator car we are dealing with unless otherwise specified.

Some of you may not be familiar with refrigerator cars or how they work. By reference to Fig. 1, you will see that a refrigerator car is like an insulated box car fitted with a raised slatted floor with an ice bunker in each end. This bunker is separated from the loading space by an insulated bulkhead with a screened air space at the top and bottom. There is an ice grate at the bottom to support the ice above the floor of the car, and a suitably trapped drain to carry off the meltage from the ice. There are two hatches with insulated plugs in the roof of the car over each bunker. When the car is used for refrigeration service, the bunkers are iced through these hatches, and, of course, the plugs are kept in place and the hatches kept closed after the cars are iced. When used in ventilation service the hatches are kept open under specified weather conditions. When used under heater service during cold weather, heaters instead of ice are placed in the bunkers and are serviced as needed through the hatches in the roof of the car. Due to the accumulation of carbon monoxide from the operation of the heaters in closed cars, it is always necessary to

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 20, 1946.

open the hatches and ventilate the cars before a man can enter to service these heaters.

The first essential for successful transportation is proper loading, not only to prevent breakage of containers en route, but to permit as much air circulation as possible through and around the containers. This generally means that the load should be stripped and braced to secure anchorage against the walls of the car and to provide air channels between the stacked containers and between containers and the walls of the car. Fully as important, if not more so, is to leave enough air space over the top of the load. Much of the spoilage found in all kinds of fresh perishables is because these fundamentals are not faithfully observed. Unlike butter, cheese, dressed poultry, and packinghouse products generally, fresh fruits and vegetables are alive and give off heat, carbon dioxide, and other products of respiration.

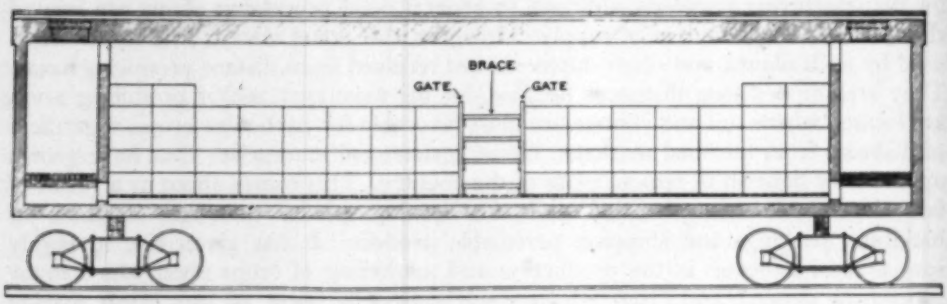


FIG. 1. Diagram showing longitudinal section through a loaded refrigerator car. In the best modern cars the floor rack is raised to a height of about 7 inches and the bottom bulkhead opening is entirely beneath it.

It is heat that we are most concerned with in shipping fresh produce, so provision must be made to get rid of the heat of respiration as well as the field heat that is contained in the produce when it is loaded, and the heat that may be transferred through the car structure. To get rid of this heat we usually must depend on air circulation from the ice bunkers, hence the necessity for leaving adequate air spaces through and over the load. It is probable that shippers have erred most often by loading too high and choking the air flow over the top of the load. This was particularly true during the war. Cars should never be loaded above the bottom of the top bunker bulkhead opening, except for short distance movements involving not over 24 hours' time, but even in such cases, heavy loading may be hazardous for some products.

The importance of proper temperature in maintaining quality in fresh produce can not be overstated. Not only is temperature extremely important in controlling diseases caused by fungi or molds, many of which will not grow outside of a certain temperature range, but with all products it is vital in slowing down metabolic activities that cause ripening and finally senescence and deterioration in quality. The rate of respiration varies greatly with different products, being highest as a rule in leafy vegetables. Among fruits, strawberries and peaches have the highest rate, while grapes and oranges are among those with the lowest. Some specific figures may be of interest. Take a carload of peaches, for example. If the peaches are at 60° F. when loaded and no refrigeration is used, their heat of respiration will cause their temperature to rise to 85° inside of 4 days. If they were picked at the proper stage of maturity, this means that they will be overripe and doubtless a pulpy mess by time of arrival unless shipped only a short distance. Or, consider a longer-keeping fruit,

like any of our winter apples. We know, from actual determinations, that the respiration rate of apples at 40° is about twice as fast as at 32°, that at 50° it is about twice as fast as at 40°; that at 70° it is again about twice as fast as at 50°, whereas at 30°, which is the storage temperature we recommend, it is about 25 percent less than at 32°. This means, then, that for every day apples are kept at 70° they respire 10 times as much as at 30°. Since the rate of respiration is an approximate measure of the rate of ripening this boils down to the fact that for every day you hold apples at 70° you cut off 10 days of their potential storage life at 30°. So it should be readily apparent why we should provide proper temperature conditions in transit. This, however, is not easy to do, nor always possible. But as with most other things, we should approach the ideal as closely as possible if we are aiming at best results.

In the time available, I cannot discuss the specific requirements of all the different fruits and vegetables that are shipped in quantity. But I can discuss them in categories and picture the varied requirements we have to contend with. In the transportation of fresh fruits and vegetables we have two general classes of products:

TABLE 1

Sugar-Starch Ratio in Peas Before and After Storage at Different Temperatures

Temperature degrees F.	Time stored—days	Sugar-starch ratio
32°	0	2.06
32	15	3.02
40	0	3.10
40	15	1.76
50	0	2.41
50	11	0.68
70	0	2.41
70	6	0.21

(1) those that will tolerate low temperature and keep best at the lowest temperature that can be maintained above their freezing point, and (2) those that will not tolerate low temperatures and therefore keep best at moderately cool temperatures. Examples of the low-temperature-tolerant products are, all leafy vegetables, onions, carrots, beets, turnips, grapes, apples, and pears. Among the products that will not tolerate prolonged low temperature are tomatoes, eggplants, cucumbers, potatoes, sweet potatoes, citrus fruit, pineapples, bananas, avocados and mangoes. The first group is composed for the most part of products native to temperate climates, whereas those in the second group are largely of tropical or semi-tropical origin.

Our difficulty in transporting these products is not lack of knowledge as to what temperature should be provided but how to secure and maintain that temperature. This is because of the limitations of the vehicle we must use, whether it be truck or refrigerator car, and because we may want to use that vehicle in any one of three different kinds of protective services, that is, under refrigeration, ventilation, or heater service. It is not too much to say that present shipping practices and the facilities available do not provide ideal temperatures under any of these services but perhaps can come closer to it under refrigeration than under ventilation or heater service. This is especially true when products can be shipped in actual contact with ice or under body icing, as we call it. By placing ice in the package with the product and then covering the load with crushed ice and shipping under standard refrigeration service we can provide good temperature conditions en route for many things

even in hot summer weather. The principal precaution we must observe is to see that the ice used is not much colder than 32° because of the danger of freezing things with which it is placed in contact. Lettuce, for example, freezes at about 31.5° on the average. Ice used directly from the freezing tanks and that from storage rooms is likely to be much colder than this. We have records of ice being used at 17°, and ice at 23-25° is not at all uncommon. It is always best to let the ice stand until it begins to melt to make sure it is at a safe temperature for use. This is the type of transit refrigeration that is used with California lettuce and carrots and peas in the pod. Indeed, it is this method of refrigerating California peas in transit that often makes them more desirable on Eastern markets than "home-

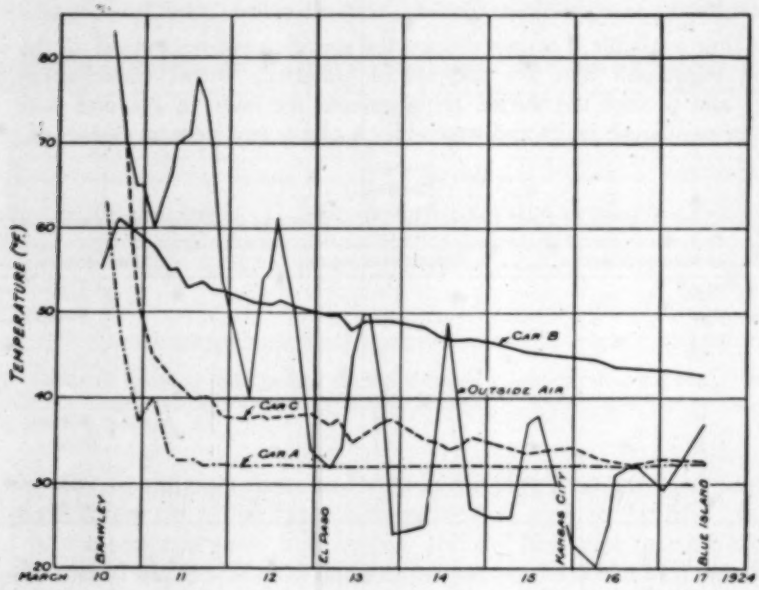


FIG. 2. Outside air temperature and average temperature of lettuce while in transit under the following conditions: Car A, top ice and package ice; car B, standard refrigeration, 5 percent salt, no body ice; car C, standard refrigeration and package ice. (From Technical Bulletin 627, U. S. Dept. of Agriculture.)

grown" peas that are not refrigerated. The effect of temperature on the sugar-starch ratio of peas, which is a measure of their quality, can be seen by the data in Table 1, taken from Jamieson's report in Cornell Bulletin 599. You will note that at 32° there is an increase of sugar, whereas at higher temperatures there is a marked decrease, more pronounced as the temperature increases.

The rate at which garden peas become starchy and lose the appealing fresh flavor that is their greatest palate appeal depends first, on the stage of maturity at which they are harvested, and second, on the temperature at which they are kept thereafter. As I have already stated, peas from California or from the Puget Sound region can be and frequently are of better quality than some locally-grown peas on Eastern markets because the shipped-in peas have been under body icing and the local produce has not been refrigerated at all.

How the method of body icing affects transit temperatures as compared with ordinary bunker icing of the cars is shown by Fig. 2. How the crushed ice is blown over the load is shown in Figs. 3 and 4.

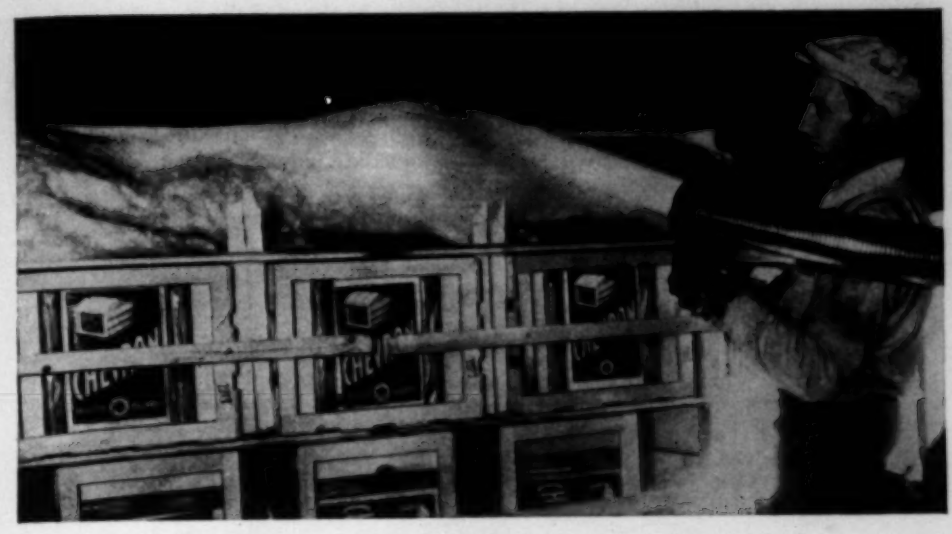


FIG. 3. Top icing a car loaded with lettuce.

FIG. 4. Finishing a top-icing job, showing the ice "crusher-slinger."

You are probably wondering about the temperature obtainable in other loads refrigerated in the ordinary way, *i.e.*, by ice in the bunkers of the car. Most of our refrigerator cars have a bunker at each end holding 10,000 to 12,000 lbs. of chunk ice. These cars are cooled by the melting of this ice, the heat being transferred from the load by the air circulation in the car instead of by direct contact as in the examples just cited. Ordinarily this air circulation is slow and is due to convection currents set up by the difference in weight of the cold air in the ice bunkers and the warmer air in the body of the car. This difference, of course, is sufficient only to

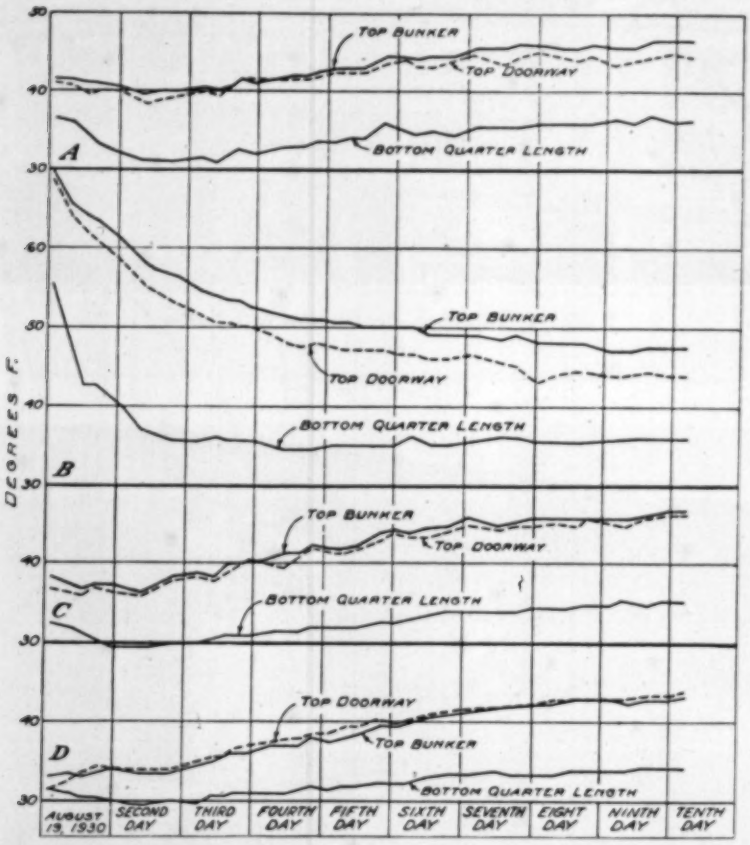


FIG. 5. Fruit temperatures in transit of carloads of Bartlett pears: A, 520-box load, precooled, standard refrigeration, 3 percent salt; B, 520-box load, nonprecooled, standard refrigeration, 5 percent salt; C, 720-box load, precooled, 3 percent salt; D, 744-box (through) load, precooled, standard refrigeration, 3 percent salt. (From Technical Bull. 434, U. S. Dept. Agr.)

provide a comparatively slow movement of the cold air from the ice bunkers out into the loading space, where it pushes warm air through the top bunker opening. This air there comes in contact with the ice, is cooled and becomes heavier, and thus continues the circulation and cooling process.

If the produce has been precooled or comes out of cold storage at 32° F. the load of heat to be removed is very much less than when the products are loaded directly from field or orchard. How much difference this makes in the transit temperatures can be seen by reference to Fig. 5, which shows the effect of precooling on the transit refrigeration of Bartlett pears shipped from Oregon to New York.

You will note that the warm pears in Car B cooled gradually in transit while the precooled pears in the other cars warmed up. Upon arrival they were about alike in temperature, but all during transit the precooled pears had the benefit of lower temperatures. What effect the transit temperature has on the rate of respiration and the life of the fruit after arrival at destination has already been suggested and must always be borne in mind. The effects of high transit temperatures are most evident in the top part of the load. With nonprecooled Bartlett pears in ordinary cars it is not at all uncommon to have the top layer so overripe upon arrival that immediate sale, if not dumping, is necessary. The uneven refrigeration of a load in ordinary

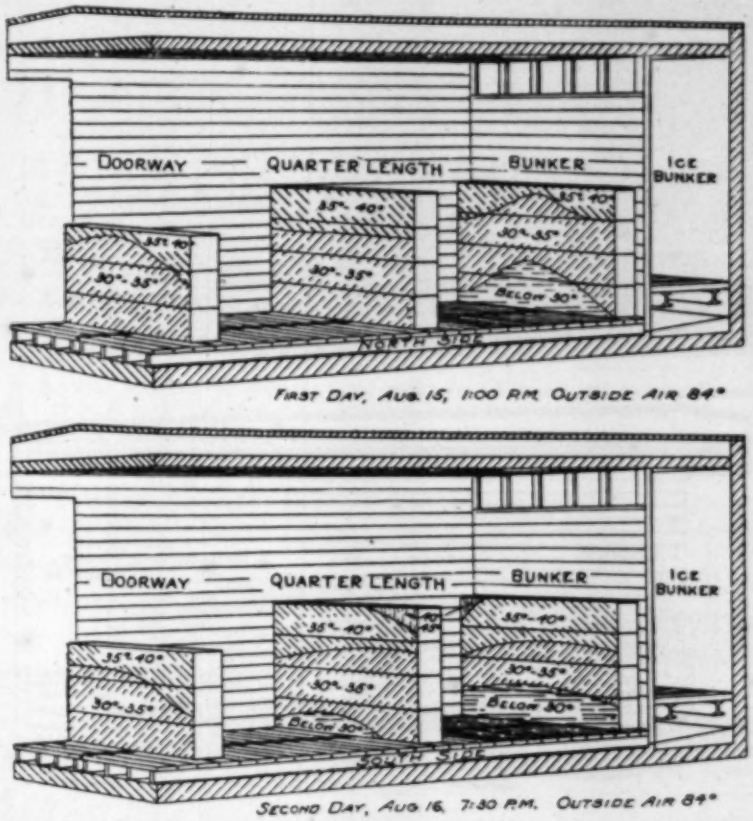


FIG. 6. Temperatures of a carload of pears during first 2 days in transit from Medford, Ore., to Jersey City, N. J. (520 boxes; precooled, standard refrigeration; 3 percent salt). After the first day the position of the car on the tracks was reversed, when the north side of the car became the south side. (From Technical Bulletin 434, U. S. Dept. of Agr.)

end bunker cars is shown in Figs. 6 and 7, which indicate by sectional diagrams the temperature zones found in a carload of pears during the first two days and the last two days in transit from Medford, Oregon, to Jersey City, N. J.

Canadian railroads are adopting a different type of refrigerator car in which the ice bunkers are located at the ceiling of the car, over the top of the load. This location of the ice gives a shorter circuit for the air movement and, consequently, somewhat faster and more uniform cooling. These cars apparently are giving very satisfactory service under Canadian conditions, but there are comparatively few of them on our lines in the United States. The improved type of car favored by U. S.

lines, and likewise, I think favored generally by our shippers who have had experience with them is the so-called fan car, as illustrated in Fig. 8. This car is equipped with a system of fans in each end located under the floor rack. The fans are operated by a friction drive from the car wheels and are so arranged that regardless of the direction of car movement they force air up through the ice bunker and out over the top of the load. Thus the direction of natural air circulation is reversed and, so long as the car is in motion, the rate of air movement is very much increased.

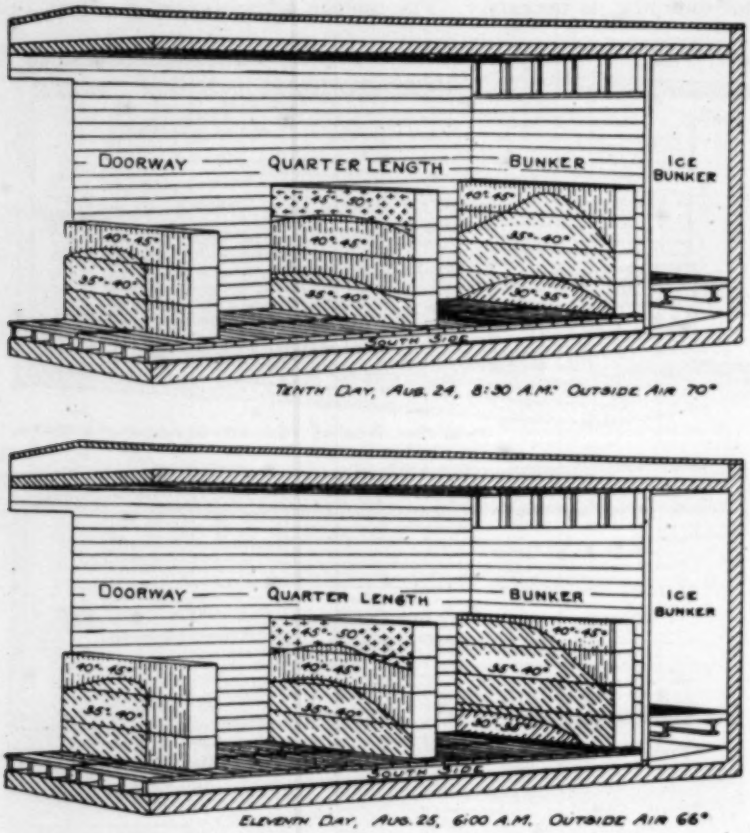


FIG. 7. Temperatures of a carload of pears during last 2 days in transit from Medford, Ore., to Jersey City, N. J. (520 boxes; precooled, standard refrigeration; 3 percent salt). After the first day the position of the car on the tracks was reversed, when the north side of the car became the south side. (From Technical Bulletin 434, U. S. Dept .of Agr.)

At 30 m.p.h. the fan output is 1,500 cu. ft. per minute and at 50 m.p.h. it is 3,000 cu. ft. When the car is standing the direction of air circulation is the same as in cars not equipped with fans and the rate is slightly less. Provided the car is kept moving this fan equipment gives the most uniform temperatures throughout the load and the best all-round performance of any we have tested. Fig. 9 shows the comparative results obtained in two cars of grapes from California to Jersey City, N. J. Note the lower range of temperature and the small spread in temperature between the top and bottom layers in the fan car (Car B) as compared with the standard car (Car G).

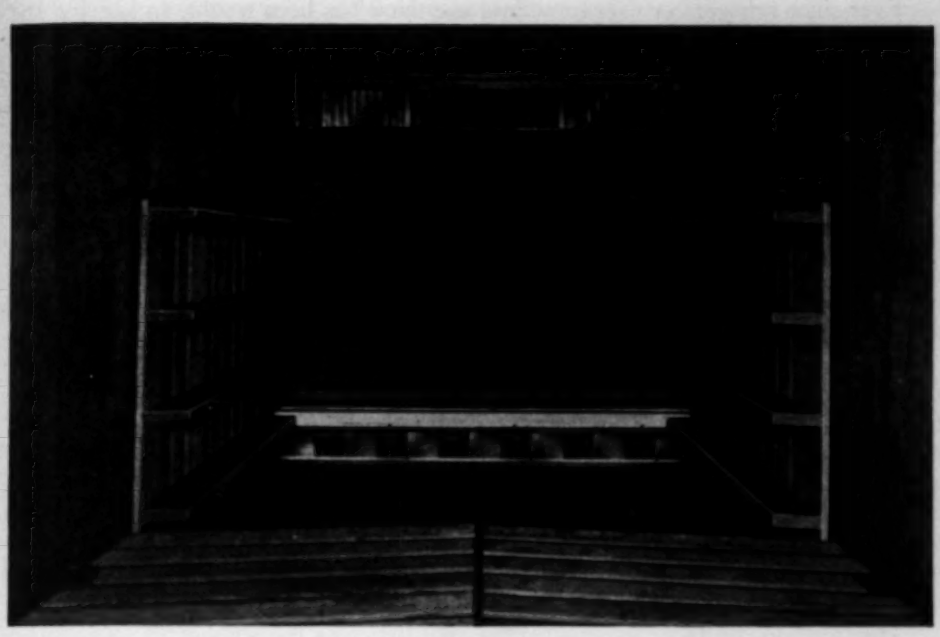


FIG. 8. Interior of a fan car showing floor racks raised in one end to reveal housings for 7 fans which reverse direction of normal air flow and force air from floor of car up through ice in bunkers and out of top bunker opening.

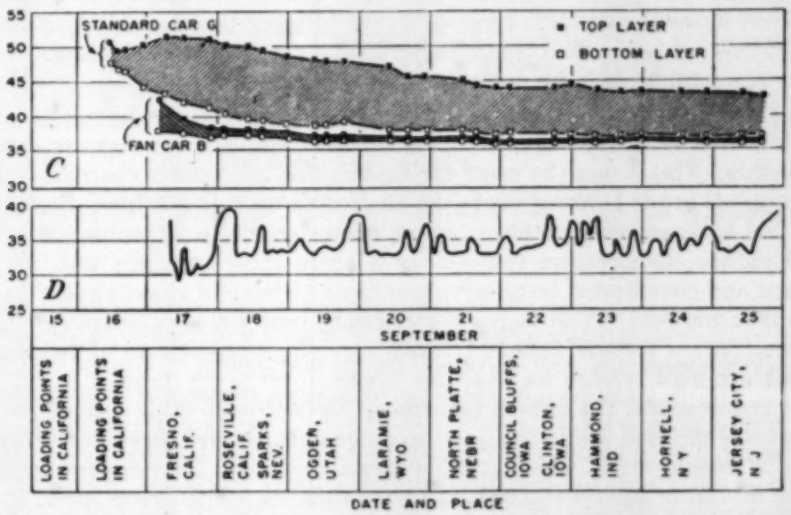


FIG. 9. Temperature in 2 carloads of grapes shipped from California to Jersey City. C. Spread in fruit temperatures between top and bottom layers in standard car G and Preco fan car B. D. Recording thermometer record of air temperatures in Preco fan car A above load at the bunker. (Transportation test 3, Sept 15 to 25, 1941.) (From Technical Bulletin 599, U. S. Dept. of Agr.)

Ever since refrigerator cars came into use there has been trouble in keeping the top part of the load cool enough to prevent spoilage and loss of marketability. The fan cars do this, as do also the overhead bunker cars. So for the first time we now have a definite prospect of overcoming this difficulty because these are the types of cars that are now being built for United States and Canadian lines. Another advantage of the fan cars is that the fans can be used for precooling at loading point by attaching a motor to the fan shaft. This is a real advantage and was especially so during the war when rules promulgated by the Interstate Commerce Commission required such high loading that ordinary precooling fans could not be installed at the top bulkhead opening. With forced air circulation as provided by these fans, heavier loads can be transported in satisfactory condition if the bunkers are kept iced and normal running schedules are maintained.

Thus far we have considered the shipment of products that will tolerate full refrigeration, but there is a great volume of traffic that is injured by being subjected to too cold temperatures. These products are very difficult to handle satisfactorily, especially under weather conditions that make the use of some refrigeration desirable, that is, when ventilation cannot be depended on to do the necessary cooling by admitting outside air during transit. It is a hard job to provide the intermediate temperature required for best results with most of these products (*i.e.*, 50° to 55°), because the refrigerator car is designed to get things cold and keep them cold, and not to cool them just so far and no farther.

The problem can be approached either by restricting the amount of ice supplied or by curtailing ice meltage en route, or by wasting some of the cooling effect of ice meltage. Use of fan cars to reduce the spread of temperature in the load and especially to avoid the lowest extreme otherwise found near the bottom bunker opening is the best insurance we now know of against chilling injury of products in this category. But thus far our best efforts leave much to be desired, as I know some of you will agree if you have received sweet potatoes that turned black inside or tomatoes that wouldn't ripen before they rotted—not to mention bananas which we are now admonished daily by radio never to put in the refrigerator.

Thus far we have considered only the cooling of perishables in transit. As you know, it is also necessary to protect them against freezing when they are shipped in cold weather. This is done by using car heaters that burn either charcoal or alcohol and are placed in the bunkers where the ice is used for refrigeration. Under heater service we have as many problems as we do under refrigeration and of the same general nature—temperature control. In a sense these problems are even more important and complicated because we are likely to have to guard against extremes of both heat and cold. With apples, for example, heater service adequate to protect the bottom part of the load against freezing may give temperatures in the rest of the load that are high enough to make the apples overripe by time of arrival if the weather requires heat throughout the trip. It has not been at all uncommon to find the bottom of the load within the freezing range under heater service and the rest of the load at temperatures which at other times would call for refrigeration service. The best insurance against these uneven and injurious temperatures found in heater service again has proved to be the use of fan cars. The comparative results obtained in fan cars and in ordinary cars are shown in Figs. 10 and 11. From these you will see that forced air circulation not only keeps the bottom of the load warm enough but also keeps the top of the load from becoming as warm as in the conventional car. When the heaters used are operated on thermostatic control the results are probably the best that can be looked for with the general type of portable heater now in

general use. Heaters using alcohol or some other liquid fuel can be controlled much better than charcoal heaters.

Mention should also be made of the type of heater used on the Canadian lines and which, so far as efficiency is concerned, probably is preferable to those used on United States lines. I refer to a heater installed on the outside and underneath the car. It is used to heat an anti-freeze solution that is circulated in coils placed under the floor racks, thus putting the heat where it is needed first and most, and largely

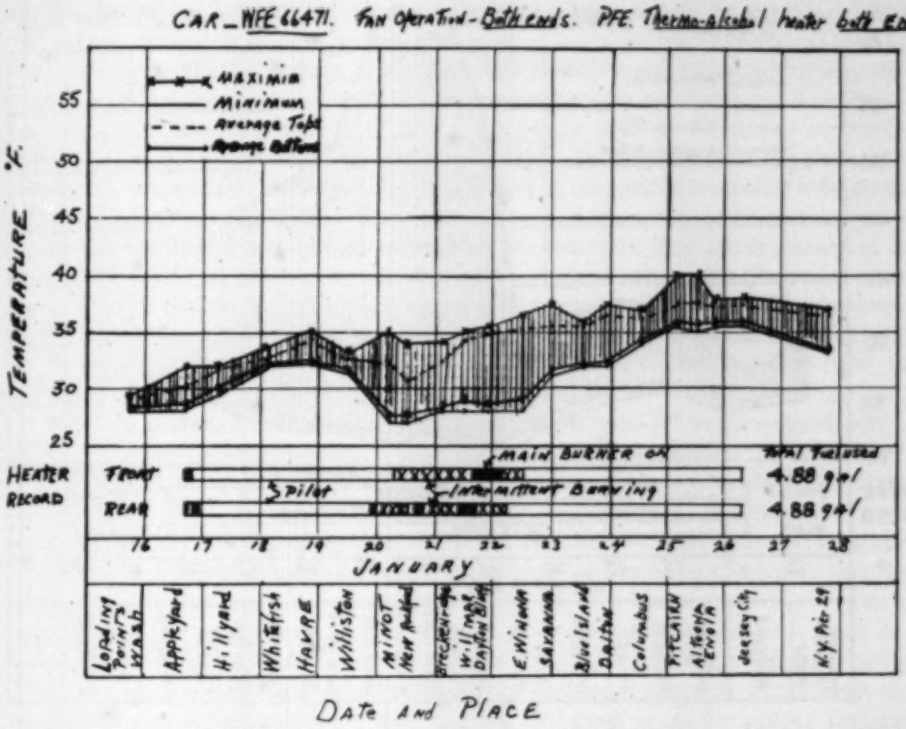


FIG. 10. Showing spread in temperature between top and bottom of a load of apples in a fan car in transit from Wenatchee, Wash., to New York City. Note that pilot lights tend to warm the load even when main burner is not lighted.

avoiding the excessive heating of the upper part of the load. The cost of this system and the necessity of making it a more or less permanent installation on a car probably will operate against its general use in this country where only temporary or intermittent heating arrangements seem to be called for on most lines.

We do not have time to go into questions of ventilation service, important as they are. However, I feel that this opportunity should not be lost to point out that neither ventilation service nor heater service, nor even refrigeration service can be rendered intelligently unless the temperature inside the car is known. Except on some of the Canadian cars and a very few experimental cars in this country no refrigerator cars are equipped with thermometers, and operators have no idea as to whether the temperature inside the car is within a desirable range or not. Without this knowledge the servicing of the car is by rule of thumb previously decided upon, or by guess or by gosh. This condition will continue until users of refrigerator cars bring concerted pressure to have the cars equipped and operated on the only basis that is truly

rational, and that is by the demands of the commodity. This can be told in transit only by the temperature to which it is being subjected. There is as much reason to insist that the operator of refrigerator cars keep such a record and be guided by it, as there is for a commercial cold storage warehouseman to do this. You, as users of refrigerator cars, have the responsibility of demanding the kind of service your business needs. You certainly need temperature control in the shipment of perishables. I hope some of you will work to see that it is provided.

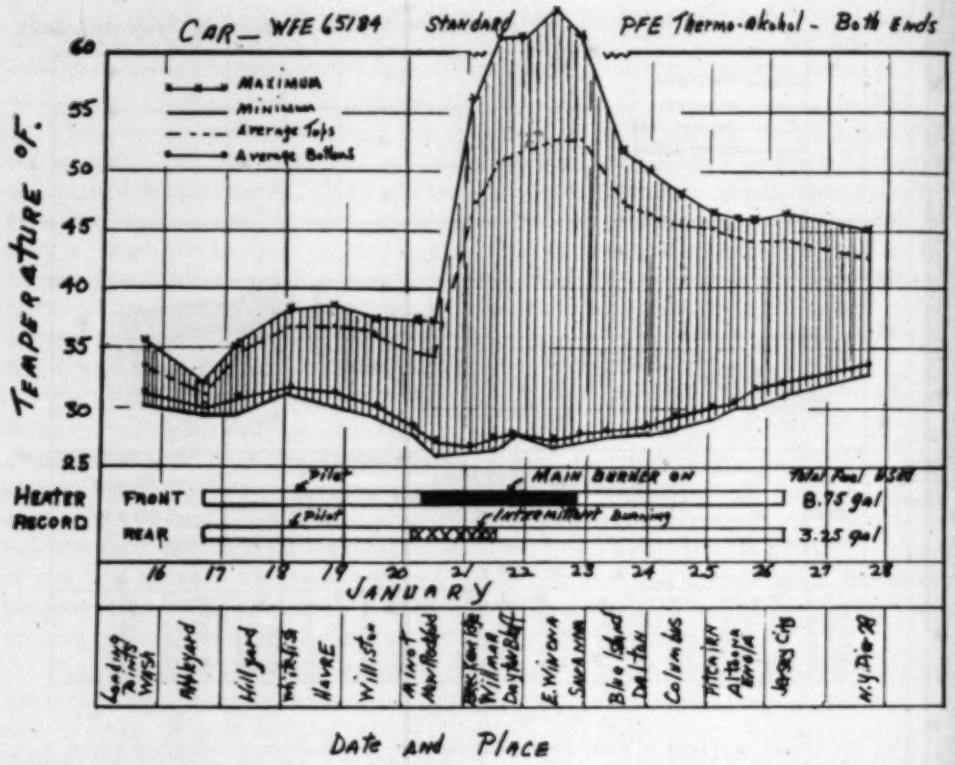


FIG. 11. Showing spread in temperature between top and bottom of a load of apples in a standard car in transit from Wenatchee, Wash., to New York City. Note that pilot lights tend to warm the load even when main burner is not lighted.

Although I may have seemed to go into great detail about the shipment of fresh perishables in refrigerator cars, I really have only touched the high spots. By now I hope I have made it plain that much more is involved in maintaining fresh fruits and vegetables in prime condition during shipment than merely loading them in a refrigerator car and starting it rolling to destination. Success in shipping perishables, as in the maintenance of quality in any food manufacturing process, depends on having and using a knowledge of special requirements. In fact, it requires an extension of quality control efforts to the fresh material from the time of harvest until it is used.

FOOD TECHNOLOGY IN THE ENFORCEMENT OF THE FOOD, DRUG AND COSMETIC ACT [1]

ALBERT C. HUNTER [2]
U. S. Food and Drug Administration, Washington, D. C.

The Federal Food, Drug and Cosmetic Act is a punitive law in that it exacts substantial penalties for violations of its provisions. The key to its enforcement may be found in Section 301 wherein those acts intended to be prohibited by the provisions of the law are set forth. However, it is a doctrine of the Food and Drug Administration that utilization of the authority vested in the enforcing agency should lead to correction and the installation of preventive measures and not merely to the imposition of fines, the seizure of offending goods, and the enjoining of establishments operating in a manner to violate the law. In keeping with the thought that the Food, Drug and Cosmetic Act is in part a corrective measure this occasion affords a welcome opportunity to speak to a national group of food technologists who are to a large degree engaged in controlling processes as they affect quality of food. It appears pertinent to discuss with this group some of the applications of food technology that can contribute to the preparation of products fully meeting the requirements of the law and to address some remarks to the technical aspects of a subject at present of paramount importance to food technologists, namely, food plant sanitation.

I am quite aware that the formulation of a definition of "food technologist" has greatly plagued those who wish to describe the talents, capabilities, and duties of the person who is entitled to such a professional classification. I confess to vagueness on that point but I am content to think of food technology as the applied science of food production and handling. In the sense that the food technologist is a person proficient in the development and application of processes of food manufacture, packaging and distribution, it may be logically held that the chemists and biologists concerned with the acquisition and application of technical information for use in the enforcement of a food law have slight claim to qualification as a food technologist. Nevertheless, a knowledge of food technology finds an every-day application in the formulation of judgments and policies which are guiding in the proper interpretations of the requirements of the law.

It frequently happens that the administration receives requests for copies of regulations pertaining to specific food products on the false assumption by the party making the request that the law or its regulations may deal with foods with greater specificity than they actually do. Answers to such requests must explain that the statute is couched in general terms and only in special cases as, for instance, where standards have been promulgated in conformity with the provisions of Section 401 or where requirements for the type of supervisory inspection authorized by the so-called seafood amendment have been announced are there regulations applicable to specific foods. Section 402 defines adulteration and Section 403 defines misbranding of food as food is broadly defined in paragraph 201 (f). In determining whether a food is adulterated or misbranded within the meaning of Sections 402 and 403 it is necessary to have a knowledge of the methods of production, processing, packaging and marketing to supplement and provide a background for the interpretation of inspectional evidence and analytical data.

---

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 19, 1946.
[2] Author now deceased.

To illustrate: Section 402 (b) states, "A food shall be deemed to be adulterated (1) if any valuable constituent has been in whole or in part omitted or abstracted therefrom; or (2) if any substance has been substituted wholly or in part therefor; or (3) if damage or inferiority has been concealed in any manner; or (4) if any substance has been added thereto or mixed or packed therewith so as to increase its bulk or weight, or reduce its quality or strength, or make it appear better or of greater value than it is." These definitions of adulteration would apply to oysters or other shellfish which have been excessively washed or inadequately drained resulting in the incorporation of water and the loss of soluble ingredients. To properly interpret and apply these definitions technical knowledge of commercial processes of handling oysters is necessary.

Let us take examples of misbranding: Paragraph 403 (g) requires conformity with standards of identity which may have been promulgated and labeling to declare the standard name of the article, and 403 (h) requires labeling to show when a product falls below a standard of quality or fill of container. Standards of identity have been promulgated for a considerable number of foods, among them being wheat flour and related products, milk and cream, some cheeses, canned fruits and vegetables, preserves, egg products and tomato products. Furthermore, we have quality standards for a few products such as canned fruit, canned peas and tomato products. Not only were these standards arrived at through knowledge of practical considerations in their manufacture but continued application of such knowledge is necessary in determining whether or not products under examination may deviate from the standard.

There are other illustrations that might be cited, for instance 403 (i), which requires label declaration of the common or usual name of the food and of its ingredients but there is no desire to belabor the point about technologists in the enforcement of the Food, Drug and Cosmetic Act. These few examples should suffice to lay a ground work for remarks concerning the extent to which technologists within the industry or serving as its consultants can practice their profession to the end that commercial foods will surpass the bare requirements of the Food, Drug and Cosmetic Act and reach higher levels of quality than can be required by the general terms of that law. It should not be amiss to say something of the burdens assumed by the agency enforcing a law. A contested seizure calls for a preponderance of evidence by the complaining agency and some courts have held that for condemnation proceedings more than a mere preponderance is necessary to prove that the product at trial fails to meet requirements to the extent charged. To convict in a criminal case means presentation of proof beyond a reasonable doubt to establish the guilt of the defendant, and at hearings to seek injunctions full and sweeping evidence is necessary to sustain the suit. Such burdens are not a cause of timidity and they invoke no hesitation in the institution of legal actions when these are indicated. They do suggest that the control laboratory acting as a policing agency imposed by the management upon itself can adopt standards of judgment for the acceptance of raw materials and for the control of plant processes that are more rigorous in their demands and more inclusive in their scope than can be imposed by the general language of a federal or state statute.

A free exchange of viewpoint between the Food and Drug Administration and those subject to the law's provisions is always welcome. Possibly such an utterance sounds strange coming from an organization which resists the idea of announced tolerances. There are sound reasons for failure to publish tolerances. With very few exceptions such as paragraph 403 (e) which among other things requires a

quantity of contents statement on the label and had a proviso that "reasonable variations shall be permitted and exemptions as to small packages shall be established" and Section 406 which provides tolerances for poisonous ingredients in food under certain very restricted conditions the Food, Drug and Cosmetic Act grants no authority for tolerances. Certainly none may be given for that paragraph which defines a food as adulterated if it consists in whole or in part of a filthy, putrid or decomposed substance. Even were tolerances permitted it is obvious that good administrative practice would not justify them inasmuch as they serve merely as goals at which the sharpshooter may aim. However, the absence of a numerical tolerance about which to talk is no drawback to a cooperative effort. The Administration is not free to approve processes or products but is always willing, within the limits of its authority and knowledge, to offer counsel and constructive criticism.

Mention has just been made of that paragraph of the Act that defines adulteration in terms of filth and decomposition. In the law it is identified as 402(a) (3). It is closely associated with 402(a) (4) which reads as follows: "A food shall be deemed to be adulterated if it has been prepared, packed or held under insanitary conditions whereby it may have become contaminated with filth or whereby it may have been rendered injurious to health." This session of your meeting is devoted to matters relating to sanitation and therefore some concentration on the meanings and interpretations of these two paragraphs appears in order. They are the legal foundations for activities by the Food and Drug Administration which have focused attention on a phase of food handling not too well attended to in some industries in the past. There has been a gratifying response and hardly a meeting of industry groups is complete nowadays without a good discussion of food plant sanitation nor are there many trade associations or large scale operators in the food field who are not active in the prosecution of programs to better sanitation.

What is an insanitary condition? Is it something that relates only to contamination with elements that may be dangerous to health? Is it something that may be corrected by a superficial coat of white paint? Our concept, and we are confident that it reflects popular opinion, is that it is broader and goes deeper than that. Modern concepts of food and drug control, in determining what is sanitary, encompass considerations of the maintenance of conditions which exclude the incorporation in foods and drugs of extraneous elements which are obnoxious and repulsive regardless of their importance as agents of disease. Accordingly, an establishment operating in a manner to invite, or permit, contamination of its output with foreign matter properly classified as filth may be described as insanitary. The objectionable matter may be the excreta of man or animal or it may be in the form of maggots, worms, insects and insect parts, rodent hairs and other material which disgustingly defile the product. In many instances the contaminants are macroscopic and detection of the avenues of their ingress into the product depends only on keen powers of observation and common sense. Other cases involving microscopic filth call for appraisal that invokes knowledge and appreciation of invisible routes of distribution.

Control of sanitation has in it many of the principles of both curative and preventive medicine. Treat the symptoms, to be sure, by ridding the plant of rats and insects, by freshening up with new paint and by providing proper light and ventilation, but go deeper by locating and eliminating the sources of contaminating pests, by installing proper facilities for inspection of raw materials, by providing for an unpolluted water supply, and by insistence upon a hygienic standard of personal behavior on the part of employees. The desired control requires a search for things

that are not always the most obvious and for a differentiation between conditions that are disorderly and those that may have a real sanitary significance. Obviously, overcrowded, dark and dingy surroundings, poorly ventilated working space, lack of morale and of personal pride in the establishment contribute to a state of affairs that is hardly conducive to the maintenance of sanitation. Any food technologist concerned with sanitation who knows his business will urge the installation of equipment for adequate lighting, air circulation and facilities for the comfort of the employees. A food and drug inspector will note and report the presence or absence of these and other similar factors contributing to the sanitary picture. However, bearing in mind the objective of the sanitary inspection to measure the figurative distance between a source of filth and the product under preparation in terms of space, time, opportunity for pollution and vehicles of transmission, the inspector, whether from a government agency or the plant staff, will concentrate on more fundamental elements.

I would like to discuss—just briefly—some of those elements that we deem to be particularly significant leaving to other times and places detailed consideration of means of their detection and control. Rats and mice are prime offenders against sanitation. They not only defile and despoil the foods with which they come in contact but they may be spreaders of disease. Their harborages must be found and eliminated. No battle against them will be entirely successful while structural faults and accumulations of trash provide harborages for them. As an ingredient of food, insects, be they flies, aphids, larvae, roaches, beetles or other member of the insect world, constitute filth in the judgment of the food law enforcement official and very apparently in the minds of judges and juries who have heard cases for condemnation based upon their presence in food. Some of the insects that infest food establishments originate in decaying refuse, some breed in infested stored materials and others come from the field or the orchard with the raw material. Their elimination through cleanup of their breeding places and through proper inspection, rejection or sorting of raw material is imperative.

In modern public health administration much attention is given to eating utensil sanitation in public eating and drinking establishments. The objective, of course, is to reduce the incidence of communicable disease but aside from the health factor it is sound sanitary control to insist on dishes and eating utensils free from repulsive residues. The same principle applies to equipment within the cannery, processing plant, freezer, fisheries establishment or meat packing house. Dirty equipment takes on considerable weight on the demerit side in evaluating the sanitary condition of the food plant.

To the sanitary minded person it is unthinkable that polluted water might be used in the manufacture of food. It is, in some places. However, a clean water supply is too fundamental to require more than passing comment. Notably outstanding in many reports to the Administration is the deplorable condition of toilets provided for the use of employees. The distance between unclean toilets in a food plant and the food handled in the plant may be great in space but may be significantly shortened by frequent and rapid movement of the carriers. It is simply basic sanitation to require proper maintenance and use. Mention has been made of the inspection of raw material. Perhaps the use of infested or otherwise unfit raw stock is not exactly within the usual concept of sanitation but the use of insect infested, rat polluted, moldy or decomposed stock is an offense against the consumer's right to clean wholesome food to be considered closely akin to matters of sanitation.

It has been the experience that even when all physical equipment has been

adequately provided the good work may be nullified by the misbehavior of personnel. Control of this element of sanitation is not simple or easy. The objectionable acts committed are transitory and not always detected. A high state of morale, education and close supervision are needed. It is not the purpose here to attempt to enumerate all the elements that contribute to an insanitary condition. That would require a manual on the subject and days of discussion. And so, we may mention in passing and then drop that phase of the subject, the elements of waste disposal, plant surroundings, plant structure and washing and cleaning facilities.

Our brief discussion of sanitation has been directed toward conditions and inspection to detect them. There are laboratory phases to the job, too. In the Food and Drug Administration the microanalysts, one or more of whom may be found in every field station, have much to do with the detection of contamination of food using methods which in recent years have been made public and which are now being further publicized. Several years ago a manual of microanalytical methods used by the Food and Drug Administration was compiled for the guidance of its own analysts and those of other collaborating governmental agencies. Unfortunately, facilities did not permit printing the manual for general distribution. In large degree the methods compiled in the manual are appearing in the Sixth Edition of the Methods of Analysis of the Association of Official Agricultural Chemists and these will be kept up to date with progressive improvements by periodic reports in the journal of that Association. Following the compilation of the manual "Microanalysis of Food and Drug Products" identified as Food and Drug Circular No. 1 was printed by the Government Printing Office. Copies of this document which discusses principles applied in microanalytical methods can be obtained from the Superintendent of Documents.

In utilizing the results of laboratory examination of samples as measures of contamination correlations as far as possible are established between the objective findings on the specimens tested and the conditions under which they were prepared. As in the case of bacteriological data, where every effort is made to relate total counts of microorganisms and differential counts of coliform bacteria with known conditions of handling, so are rat hairs, insect parts and other extraneous substances appraised as measures of faults in sanitation. There is sometimes a disposition to deride the microscopic size of the filth elements detected, for instance, a rat hair 5 mm. or so in length or an insect head, wing or leg. The evaluation goes further than the measure or weight of the filth elements found. It involves realization and appreciation of the conditions of handling which permitted a contamination that can be found in any degree after the manipulations and processing incident to manufacture.

There is no disposition to point an accusing finger or to claim that food production in general is carried out in grossly insanitary manner. Nevertheless, we would not be honest with each other nor indeed with ourselves if we did not admit that either through pride in antiquity with attendant reluctance to change the old order of things, ignorance, blindness or indifference, some bad practices in food handling have been allowed to establish themselves and grow. In the Food and Drug Administration we assume no superior airs that we know more about these things than you do. Nor can we furnish answers to all the questions. The responsibility for running the establishment and running it properly must rest upon the management. And that is where the food technologist plays his part. There is no question that sanitation is a part of food technology. Every technologist concerned with food manufacture and distribution might well consider himself a cooperator with, and at the same time a rival of the law enforcement official in demanding standards of sanitation beyond those which can be exacted by any state or federal food law.

COST DETERMINATION AND ALLOCATION IN FOOD MANUFACTURING OPERATIONS[1]

W. L. CAMPBELL
Massachusetts Institute of Technology, Cambridge, Mass.

Many manufacturing companies, both large and small, have failed because of unheeded conditions within the business. Even small concerns often do not accurately know their costs, leading to demoralization of markets and no profits, usually blamed on some one else. Accounting often has been considered a mystery field in which only the initiated could dare to strike a balance sheet or prepare an earnings statement. Operators of small businesses have carried their figures in their heads and hoped that the guesses which they put down once a year on their income tax returns were near enough right to keep them out of jail. That which appeared to be good enough for Uncle Sam should be sufficient for anyone else.

As manufacturing establishments increase in size the complications of accurately determining what happens are multiplied. Finally, we find that statistics either in the form of figures or graphs become a necessity where formerly a cash book and receiving and shipping records comprised about all the accounting that was needed to run the business.

Figures or their transfer into the more illustrative graphs are merely the components of a larger picture, just as brush strokes on a canvas. The figures may be accurate to the sixth decimal place or balance to the last mill, but unless they convey a proper picture to the person for whom they are prepared, they are worse than useless. Some people, even though they may be few, understand what the artist is trying to convey in some of the modern futuristic paintings, but most everybody, even those of low I.Q., understands a Rembrandt painting of a "Dutch Merchant" or a George Innes portrayal of an "Afternoon Landscape." We have the same things in business accounting. We have all seen various systems so complicated that only the author understood them and there was question whether he did very thoroughly, so further experts had to be hired to interpret the figures. Then, in contrast, we find some manufacturer with a minimum amount of calculations who can put his finger on the salient points of his operation at any hour; and it is like a breath of fresh air in a hot subway. There are fads in figures as there are in painting or music. We have had wholesale stampedes to systems, the more complicated the better, just as we have had stampedes to futuristic art or some so-called modern orchestral music; and yet there are few of us, if we are honest with ourselves, who do not get more of an understanding of great harmony from simple foundations by looking at such paintings as "The Angelus" by Millet or hearing such old classics as Beethoven's "Moonlight Sonata."

After all, there are only three factors in any production cost record: labor, material, and overhead. Accurate time cards are the foundation of proper labor cost records. This accuracy is insured by daily inspection of the cards and by using the cards at different times during the day. Then foremen's time books and job cards furnish means of distribution of the labor and if checked with the time cards furnish a double check on the accuracy of both. Whether the labor is direct or indirect, applied or unapplied, productive or non-productive, all names for the same division, is less important than that the labor be charged to the particular department using it. For instance, whether a trucker be direct or indirect labor in a machine room is not nearly so important as the fact that he ought to be charged in the machine room labor and not lost in general overhead.

[1] Presented before the Sixth Annual Food Conference, Buffalo, N. Y., March 18, 1946.

Let's leave the labor figures for a moment and consider the item of *Material.* Accurate receiving records and insistence on requisitions for all material issued are the fundamentals here. It is then desirable to have stock cards for each different item, either on the stock bin, in the supply room, or on your stock keeper's desk, depending on conditions and layout. A perpetual inventory should be kept in the main accounting office. Of course, once a year at the time of the general audit the actual inventory is checked with the book inventory. Many companies check for their own information once a month. However, I've found that a check of a few different items, every day, of the book record, against the card record, against the actual inventory requires very little time, yet keeps the records accurate and eliminates overages or shortages. We have heard of many famous cases of inventory swindles that have appeared in the newspapers, like the McKesson & Robbins case. Most of these would have been eliminated if frequent accurate checks of inventory were made not only by different members of the accounting department, but by responsible officers from time to time. In by far the majority of cases of defalcation, the company is as responsible as the individual since the system was so lax as to encourage carelessness. A sound and frequent check is liked by the good employees as it proves they are honest; it acts as a deterrent for the weak ones who know they would be soon detected; and it is a positive obstacle to the crooks who will be caught more quickly.

Some business men fail to realize that savings in the cost of materials without sacrifice of quality is just as valuable a saving as one in labor expenses and often easier to obtain. People will purchase on a delivered basis because it saves bother when they could buy at the maker's plant and utilize such freight privileges as milling-in-transit with consequent savings in money. Transportation charges are just as much a part of the material cost as is the value of the material itself. A seller who sells on a delivered basis is usually careful to add plenty to cover the transportation charges so there is in many cases ample room to make savings on a particular shipment if the customer will take the trouble.

All other expenses besides labor and material become *Overhead.* The closer this can be broken down by departments the easier it is to control. For instance, on such items as light, heat and power, it often pays to put in supplementary departmental meters in order to segregate the charges and then find out where the wastes really occur. Allocation of engineering services as well as other general overhead items to the departments involved usually insures your getting your money's worth from these general services.

As previously mentioned, figures are only valuable when they convey a correct picture of conditions to the person who is using them. If the boss has no interest in figures, very shortly nobody else has either. But if the boss checks some of the figures himself, now and then, you would be surprised how their accuracy improves immediately. There is no better way to get an appreciation of what figures mean than to spend an hour with the accountant in deciding how some of the overhead items should be allocated. For instance, should the gas bill in a bakery be allocated as between departments on a per-pound-of-finished-product basis, on a man-hour basis, or on an oven-hour basis? When you decide that rationally you know what your operations are. Many companies have instances where they think a particular department or item is profitable. However, when the legitimate overhead is charged against the department or item, the picture is entirely changed. Many items of overhead involve no argument. On the others it is better to make a reasonably intelligent trial of any basis that appears logical, and then make later modifications as needed, rather than hold up the entire program.

After all the items of overhead which can be so handled, have been directly allocated, all of the balance of general office and executive expense can be grouped as general overhead. This can be allocated as between departments or by items on a relative dollar value of product basis. Sales expense can be similarly apportioned for cost purposes except that definite allocation should be carried out here insofar as possible.

Having the total cost figures of labor, material, and overhead and the amount of production, the unit costs are directly available. Nevertheless, many people try to make it complicated. For instance, on a railroad you wouldn't figure car oil per locomotive mile or valve oil per car mile; yet in the same vein, I had the head of the treasury and accounting for a large company tell me with a straight face on an expansion program that the new capital expenditures plus the existing value of facilities should be divided by the previous year's production in order to get the future capital overhead unit costs. That should be classed with another request I once made for the average train load eastbound over a certain railroad division on a particular day. The young man who furnished the answer added all the engine numbers and divided by the number of trains and was surprised that there should be any question as to the accuracy of his computation.

Another fruitful source of argument is the charge for depreciation which is of course included in overhead. It is easier to visualize if we consider the definition. Depreciation is the periodic charge made against operations consisting of a percentage of the cost of equipment so that when the equipment is retired its cost has been fully charged off. Retirement may come from obsolescence as well as from wear and tear. Therefore, this factor must also be considered in setting the percentage of depreciation charge. If equipment cards are kept for each piece of machinery and the depreciation figured by items, it becomes easy to justify on any inquiry.

In the keeping of unit costs, I prefer to show the actual costs currently rather than just show fluctuations from a standard cost. We have all seen standard costs which were subject to a lot of modifications. Variations from such a standard do not mean much and if on the plus side have a tendency to lull one into a feeling of security, which is false. Standard costs have a place and furnish interesting comparisons but if actual costs are used currently there is the continual incentive for their reduction with no alibi that things are good enough because they are better than standard. Standards are only estimates anyway, and estimates vary with the people who make them or with conditions under which they are made.

Let's take a definite case. An accounting procedure and cost method that was satisfactory for bakeries with production from 74,000 to 674,000 lbs. of bread and 6,000 to 86,000 lbs. of cake per week had the following items of comparison:

For Bread

Percent water absorption, by varieties
Percent yield, based on ingredients used
Difference between dough made and standard required (in pounds, dollars, and percent)
Dusting flour per 1000 lbs. of bread
Greasing material per 1000 lbs. of bread
Cripples (in pounds and percent)
Pounds of production
Direct labor cost, divided between bakers, wrappers, packers (in total dollars and in dollars per 100 lbs. of bread produced)
Direct labor hours (divided between mixing, make-up, oven, wrapping, and packing)
Percent labor accomplishment, based on standards revised every six months and determined by the type of equipment and layout for the plant (and divided between mixing, make-up, oven, wrapping, and packing, and average for the whole plant)

The best previous record in pounds per man hour, average for the whole plant

For Cake

Pounds of net production divided between cake, doughnuts, pastry, specialty bread, rolls and buns—total
Cripples, in pounds and percent divided over the same categories
Percent of dough shrinkage in various types of cakes and pastries
Percent shortening used for doughnuts
Percent icing difference
Percent labor accomplishment compared to standards set as in bread
Actual hours, divided between making, icing and packing, shipping, total for cake, total for doughnuts, total for pastry, total for rolls and buns, plant total
Dollars of direct labor (divided in same way)
Pounds per man hour (divided in same way), and
Direct labor cost, per pound (divided in same way)

Only one or two people were needed to keep these records in each plant. The cost accountant became the right-hand man of the bakery superintendent and these men were excellent recruits for our operational positions. Two finally became bakery superintendents, a third became a branch factory superintendent and a fourth became superintendent of a printing plant.

This grouping is by no means meant to be all-inclusive. It is merely an example of a simple tabulation which will show the operating personnel what they are doing with the factory under their control. However, such data as this plus the inventory records plus the other monthly bills and charges will enable nearly anyone to compile his costs whether by items, departments, or in total. Having accurate costs it is easy to set proper sales prices and determine profits. The proof of the pudding is always in the eating and with this simple control record the general superintendent of thirteen bakery plants was able in two years from an already good performance, 60 percent less labor cost than an average of the American Bakers Association, to further improve his quality, increase his pounds of production per man hour by 45 percent, and further reduce his direct labor cost by 26 percent despite rapidly rising labor rates.

I can't emphasize too strongly that the figures are no good unless they convey an adequate picture to the man who is going to use them. If they convey an erroneous picture, they are worse than useless. Therefore, simple figures have much more chance of conveying the meaning intended than complicated ones.

In the Saturday Evening Post of January 5, 1946, Mr. Robert W. Johnson, chairman of the board of Johnson & Johnson, the great medical supply manufacturer of New Brunswick, N. J., has a most interesting article on management control. His comments after long exposure to various systems paralleled some of the points I've been trying to impress on you. The controls should be as simple as possible, but as accurate as you can make them. This accuracy is attained by being personally acquainted with the operations, so the figures mean something. Mr. Johnson became brigadier general in the Ordnance Dept. in charge of the N. Y. Ordnance Office during World War II so had ample opportunity to see small business as well as big business supposedly operating at the peak efficiency of full production. You will be interested to read his comments. He repeats the slogan which was current around Washington that a coordinator is one "who makes organized confusion out of regimented chaos." To make head or tail out of some of the corporation records I've seen almost requires a magician and I can sympathize with Mr. Chandler who was confined in an insane asylum in the Carolinas and wired his brother when the latter married the opera singer, Cavaliri, "Who is looney now?"

There is no panacea for these ills, but personal attention to the mathematical structure of your business will be enlightening, conducive to a better understanding of your position, and highly profitable.

PROPER SPECIFICATION FOR USAGE OF STAINLESS STEEL TO ACHIEVE SANITATION AND CORROSION RESISTANCE IN FOOD PROCESSING[1]

RICHARD C. CUNNINGHAM
Industrial Steels, Inc., Cambridge, Massachusetts

Of the 28 types of stainless steel recognized by the American Iron and Steel Institute, four (types 304, 316, 303, and 404 FM) are discussed as being of major interest in the food industry. These meet seven important specifications. One important requirement, ease of fabrication, is being steadily improved.

When we consider the equipment problems of a certain industry, it is desirable to reduce the factors involved to a minimum. In this paper, we are to discuss the usage of stainless steel as a material of construction for plant equipment in the food processing industry to achieve sanitation and corrosion resistance. It becomes necessary, therefore, to consider such widely different problems as those involved in the processing of milk and dairy products, canned vegetables and soups, fruit and fruit juices, meats, candy, bakery products and beverages. You can see that it will be impossible to cover all of these specifically and a certain amount of generalization will be necessary.

When the metallurgist is faced with the question "What material will be satisfactory for the equipment in a certain process?," he must immediately ask for a definition of the word "satisfactory." Do we want the lowest initial cost? Do we want the greatest freedom from contamination? Do we want the highest strength-weight ratio? Do we want maximum corrosion resistance? Generally, the final answer to all these questions is a grand compromise. In other words, we want that material which will most nearly fulfill all the requirements.

Fortunately, these requirements are approximately the same for all the before-mentioned divisions of the food processing industry. We have asked plant engineers, food technologists, and superintendents of food processing plants just what specifications the ideal material of construction should have. The answers have been generalized and are listed in the following order of importance as we see them:

1. It must not contaminate the product.
2. It must be easy to clean.
3. It must not be corroded by operation conditions.
4. It must have good physical properties.
5. It must be readily available in required forms.
6. It should have a reasonably low initial cost.
7. It must have a low maintenance cost.
8. It should have an attractive appearance.

Now, having set up the general specification pattern for the ideal material, let us superimpose on this pattern the physical, chemical, and metallurgical characteristics of stainless steel and see how near is the fit.

First, perhaps a few words of explanation regarding the metallurgical nature of this material, "Stainless Steel." We use the singular form advisably. There are really 28 separate and distinct alloys which are recognized as stainless steels by the American Iron & Steel Institute. In addition, there are literally hundreds of variations of the standard analysis which are especially manufactured or specified for

[1] Presented before the Seventh Annual Food Conference, Boston, Mass., June 3, 1947.

certain applications. Fortunately, the requirements of the food processing industry allow us to eliminate all except four.

Metallurgically speaking, stainless steel is a ferrous alloy containing at least 12 per cent chromium. It is this hard, corrosion resistant element, in solid solution with iron and sometimes other elements which impart the well-known stainless characteristics to this alloy known as stainless steel.

It might be well here to look into the mechanism of corrosion and explain why this addition of 12 per cent or more chromium so greatly improves the corrosion resistance of the basic iron. It has been fairly well established that in substantially all cases of corrosion, the driving force of the corrosive reaction between metal and environment is electrochemical. The resultant electrochemical potential varies with the corroding media and the metal, and determines the *tendency* of the reaction to proceed. The *rate* of corrosion is determined mainly by the resistance to the continued progress set up by certain of the corrosion by-products. The initial rate of corrosion is usually comparatively rapid and slows down as the protective, by-product film forms. It is therefore essential to have in the metal, alloying elements which promote the rapid formation of the protective film, and which form a film that is nonporous and durable.

Metals which may be alloyed with iron to aid in building up these self-protective films at reasonable cost are relatively few and include principally chromium, copper, nickel, silicon, molybdenum, and aluminum. Of these, chromium, when used in amounts exceeding about 12 per cent, is by far the most effective under most conditions. The protective oxide film formed by the chromium-iron alloy is very thin, almost of molecular thickness, invisible except when colored by high heat, and forms instantly when exposed to oxidizing conditions. This film can be destroyed by reducing conditions such as those present in halogen acid solutions, but fortunately, we seldom encounter these conditions in the food industry.

Elements other than chromium are added in smaller quantities to improve the protective characteristic of the film. The common "other" elements which are added to the iron-chromium alloy are, nickel and molybdenum. Sulphur or selenium additions are occasionally added to improve machining characteristics and have little or no effect upon corrosion resistance.

As we mentioned a moment ago, we will confine our interest here to only four of these many stainless steel analyses. First and most important is the basic 18-8 stainless steel which contains 18 per cent chromium, and 8 per cent nickel. In addition to improving the corrosion resistance, nickel also adds materially to the mechanical strength. This alloy is nonmagnetic, easily welded, resistant to corrosive attack by nearly all of the media encountered in the food processing industry, and has a high strength-weight ratio.

It is occasionally necessary to use an alloy which is even more corrosion resistant than the basic 18-8 Type 304 alloy. When such requirements arise, we use the 18-12 SMO or Type 316 alloy. This contains somewhat higher nickel, 12 instead of 8 per cent, and 2 to 3 per cent molybdenum. The cost of Type 316 is considerably higher than Type 304 and need only be used where maximum corrosion resistance is required.

Because of high strength characteristics, these two chromium-nickel alloys are rather difficult to machine. Consequently, for these particular applications where close machining tolerances and smooth machined surface are essential, we use a modified 18-8 which has the same chromium-nickel content but to which has been added a small percentage, usually about 0.25 percent, of sulphur or selenium. This allows the part to be drilled, turned, threaded or reamed with much greater ease.

This free machining 18-8 alloy is the A. I. S. I. Type 303, and is used extensively for bolts, nuts, machine screws and other parts machined from bars or wire.

Unfortunately, the high corrosion resistant 18-8 alloys are not particularly satisfactory for sliding or rotating bearing surfaces. Neither can they be hardened by heat treatment. Therefore, we must turn to a straight chromium-iron alloy for such items as bearings and bushings. We generally use a 1 percent carbon, 18 percent chromium alloy, with selenium added, for free machining characteristics. Such an alloy can be machined to close tolerances and then hardened to approximately 60 Rockwell "C." When ground and polished, it has excellent bearing characteristics. This is the A. I. S. I. Type 440 FM. It does not have the excellent corrosion resistance of the 18-8s but when properly hardened and ground does give very satisfactory service as a bearing material under corrosive conditions. Most stainless steel ball bearings and bushings are made of this alloy.

So we see that all this complicated metallurgy of the stainless steels boils down to only four important alloys and of these four, only one, the Type 304, accounts for at least 90 percent of all the requirements for the food processing industry. It is well to remember, however, that we do have other alloys which are available to the food industry when the need arises for their special chemical or physical characteristics.

Now let us go back and review those requirements we set up as essential specifications for a material of construction for food industry equipment. First, and certainly most important from the viewpoint of the food technologists, is the matter of contamination. This general requirement should logically be broken down into two classifications. First, the direct or chemical contamination of the product by the metal used for the equipment, and second, the indirect, bacteriological or biological contamination resulting from the use of the particular material for construction of equipment.

Speaking of an ideal material for construction of dairy equipment, Trebler *(5)* lists as a requirement the following: "It should be insoluble in the product under all conditions encountered and it should not be toxic nor have deleterious effect upon flavor or keeping quality of dairy products."

There has been a lot of excellent research work done on the question of food contamination by metals or metallic ions. For instance, a very comprehensive study of contamination of food cooked or stored in contact with iron-chromium-nickel alloys has been reported by associates of the Harvard School of Public Health *(4)*. This work indicates that, regardless of the pH value of the food studied, the amounts of metal dissolved are so minute that they have no hygienic importance. The foods studied covered the range of acidity between that of gooseberries and that of chicken. In no case was any change noted in the appearance or taste of the food.

When we consider the toxicity of the possible corrosion products, we find that none of the alloying elements involved in stainless steel are listed as possible food poisoning metals. Dack *(2)* lists the following metals as possible food contaminant poisons: animony, arsenic, cadmium, lead, mercury, and zinc.

On the other hand, Clifcorn and Peterson *(1)* have shown that the use of copper equipment in the preparation of tomato juice resulted in a serious loss of Vitamin C, and LaQue *(3)* reported that as low a concentration as 2 p.p.m. of copper in canned peas was extremely detrimental to both the peas and the liquid around the peas. Chromium, nickel, tin, and zinc up to 80 p.p.m. by weight had no effect on color or taste. The same author reported the results of tests on the effects of metals on canned corn. Here again copper was the bad actor, causing a definite blue black darkening by as little as 2 p.p.m. of copper. Tin and zinc had a slight bleaching

effect when present at 20 p.p.m. or more. The only effect of chromium was to give the corn a slight pinkish cast when present in concentrations greater than 50 p.p.m. No effect on the taste of the corn was reported. Tests on tomato juice reported by LaQue *(3)* also indicate that copper had a distinct effect on both taste and color of the juice at 16 p.p.m. concentrations, while iron, chromium, nickel, tin, and zinc in concentrations up to 80 p.p.m. had no effect on taste or color.

While these reported results are only a fraction of all work done along this line, it is an indication that some metals, such as copper, are definitely injurious to the food products and others seem to have no serious detrimental effect, at least within the range of concentrations studied. These findings are further substantiated by a statement prefacing an article by Trebler *(5)* in which he says: "The dairy industry is today definitely living in a stainless steel age, while ten to fifteen years ago, it was just as definitely living in a copper age."

If stainless steel meets the exacting requirements in the dairy division of the food industry, there seems reason to believe that it would be equally satisfactory in the other divisions. This statement is substantiated by the fact that stainless steel equipment has been in service in practically every branch of the food industry and reports indicate no direct contamination of a product by this metallic equipment where the proper alloy was used and correct fabricating technique followed.

We also know that the high ductility and tensile strength of the stainless steel precludes the possibility of mechanical contamination such as that occasionally encountered in the use of porcelain enamel or glass lined equipment. Even by the most severe mechanical abuse it would be impossible to chip or splinter stainless steel equipment.

When we consider bacteriological or biological contamination, the metallurgist is unquestionably at the mercy of the mechanical engineer and the designer of the equipment. The best we can do is to give the design engineer a material which can be fabricated with the least difficulty into the equipment which he knows by experience will give the least possible chance of contamination. For this requirement, the design engineer wants a material that can be welded so that open seams and crevices can be avoided. He wants a material that can be ground and polished to a smooth bright finish and to which the product will not cling. He wants a material that will withstand the action of the varied cleaning practices used in the "clean up." He wants a material available in cast form which is free from blowholes and porosity. Given a material which will meet all of these specifications, the experienced design engineer can produce a piece of equipment that will meet the most exacting requirements for noncontamination of product.

Now let us see how stainless steel meets these exacting requirements. In the early history of stainless steel, which, by the way, was relatively a short time ago, one of the most persistent complaints about the new metal was its weldability. It was hard to fuse, the welds were porous, warpage and distortion was a problem, and the weld metal and adjacent areas showed reduced corrosion resistance. Knowing that welding was a logical method of fabrication, both the stainless steel manufacturers and the welding equipment builders concentrated on this problem. The results of this research work are most gratifying. We have estimated that about 68 percent of all stainless steel tonnage produced today is fabricated by welding. The welding engineers have given us many new methods of welding for stainless steel fabrication. Now we can use shot-weld, oxy-acetylene flame, metallic arc, atomic hydrogen, heli-arc, or inert arc welding, all of which have their own special place in stainless steel fabrication.

The metallurgists found that carbon in the early stainless steels was the cause of much of the welding trouble. Now we know how to produce the stainless with a carbon content so low that it will have no effect on the welding characteristics or the corrosion resistance of the fabricated part after welding. We have learned to add a stabilizing element such as columbium or titanium, so that any remaining carbon will be immobilized and thus prevented from causing trouble. New welding electrodes have been brought out with core wire analyses properly balanced to give the weld metal exactly the desired physical and metallurgical properties and coatings have been developed to properly protect the metal from oxidation during welding. All of this means that stainless steel can now be fabricated by welding into equipment which will be free from open seams or cracks, have rounded, easy to clean corners, with no bolt holes or rivet heads to collect refuse.

We have listed as a second requirement, a bright smooth surface to which the product or refuse will not cling and which will remain bright and smooth during the years of operation. We have had to appeal to the metal finishing engineer for help here, but we now can produce a sheet, plate, bar and tube finish which meets all the above specifications. It is smooth, bright, free from pits or scratches, and presents minimum possible opportunity for adhesion of food particles. We refer to the standard No. 4 polish which is almost universally used for food handling equipment and which is standard throughout the stainless industry. This finish also insures maximum corrosion resistance to the stainless part so polished.

We might mention here that considerable work is being done in the dairy industry now to develop an even more satisfactory stainless finish than the No. 4 polish. We are working toward a so-called No. 7 finish which is produced by finish grinding with a very fine abrasive and then buffing to partially remove grind lines. This results in a sheet finish having much higher reflectivity and almost a mirror finish.

Of tremendous interest to the design engineer and the food technologists concerned with the prevention of bacteriological contamination is the work being done by the manufacturers of stainless steel tube, pipe, and fittings of the so-called "Sanitary" type. This type of pipe and fitting is highly polished on all inside surfaces which come in contact with the food product. Furthermore, they are so designed that with little effort the whole system can be dismantled for periodic cleaning. It is astounding to see two men with only a couple of wrenches, dismantle, clean and reassemble the entire complicated piping system of a large milk handling plant in less than an hour's time. Every piece, including fittings, pumps, valves, and pipes, is taken apart piece by piece, given a thorough cleaning and disinfecting, and then reassembled. It is only because of the smooth bright interior finish on these stainless parts and the excellency of their design that such a procedure can be followed except at prohibitive expenditure of time and money.

And that brings us to the third point which deals with cleaning methods and practices, and a material to withstand them. The methods of cleaning food processing equipment are as numerous as the plants themselves and range from blasting the parts with highly chlorinated water at 600 p.s.i. pressure to sloshing them off with a bucket of cold water. Generally speaking, the medium is water, to which may be added chlorine, or other disinfectants, strong alkaline detergents, abrasives and steam. The high degree of corrosion resistance of the chrome-nickel stainless steels adequately handles the detergents, disinfectants, and water. Likewise the stainless steel with its high tensile strength and yield point and relatively high hardness, withstands the mechanical attack of high pressure water, scouring, brushing, and abusive handling.

Fourth and last, is the need of a material which can be obtained in wrought or cast form, free from blow holes, deep pits and porosity. This is of prime importance in preventing contamination as such blind openings are a haven for all manner of undesirable bacteria. Wrought stainless steel products, sheets, tubes, pipe, bar, and plates, have never been troublesome in this respect as the hot or cold deformation necessary to reduce the original cast ingot to the finished shape is usually sufficient to close up all such defects. On the other hand, castings have been the problem child. Much has been done to improve this condition but it is still with us. We have changed the make-up of the casting charge. We have added new elements to the melt to improve fluidity and prevent gassing. We have changed mold design and casting practice. We are using X-ray, radium and ultra-violet light inspection. However, much new research work is in progress now, and our inspection departments are becoming more efficient at finding and rejecting porous castings, so the cast stainless steel picture is definitely improving.

Thus far in our discussion, we have not only been able to fit stainless steel into our pattern for a generally satisfactory material from a contamination standpoint, but have also touched on some of the other basic requirements. We mentioned the matter of direct contamination by metallic ions resulting from corrosive attack of the metal equipment by the food product itself. This corrosion resistance of stainless steel to attack by conditions in the food industry is substantiated by literally thousands of laboratory and field tests made by many different and reliable corrosion laboratories. We do know of some isolated cases where food acids, under certain conditions prevailing in food processing, have been seriously corrosive to stainless steel equipment. One well remembered case was in connection with the manufacture of a particular salad dressing. Wine vinegar was heated in a steam jacketed kettle in the presence of considerable quantity of common salt. A severe chemical corrosion of the stainless kettle resulted in a very short time. Investigation indicated a break down of the passivity of the stainless by the hot solution containing acetic acid and the chloride radical. Two solutions were suggested, both worked. The higher corrosion resistant Type 316 stainless (18-8 plus molybdenum) was substituted for the Type 304 in the lining of the kettle. Second, the addition of salt was not made until after additions of vegetable oils and thickening. These additions acted as a buffer or inhibitor and prevented attack on the regular Type 304 kettle lining. Such instances have been valuable in guiding our recommendations and preventing us from foolishly offering stainless steel as a panacea to cure all corrosion troubles in the food industry.

We should now consider the physical properties of stainless steel to determine if it will give adequate strength-weight ratio and satisfactory resistance to wear. For any material of construction, the strength-weight ratio is most important. We can consider the yield point as a measurement of strength inasmuch as none of our equipment parts should be stressed beyond that point. And the specific gravity is an accurate table for comparing weight. Therefore let us use yield point over specific gravity as the formula for measuring the strength-weight ratio of the materials to be considered. The 18-8 stainless steel in the fully annealed condition (which is the proper state for this type of work) has a yield point of 35,000 p.s.i. The specific gravity is 7.92. Thus the strength-weight ratio is $\frac{35{,}000}{7.92}$ or 4400. The following table shows this same strength-weight ratio for a list of materials which might be considered for food processing equipment.

TABLE 1

Material	Strength-Weight Ratio
Stainless Steel	4400
Inconel	4100
Monel	3950
Ingot Iron	3700
Cupro-Nickel	3380
Nickel-Silver	2280
Nickel	2250
Aluminum	2200
Copper	1060
Block Tin	230

You will note that the Type 304 stainless steel has a higher strength-weight ratio than any of the other materials recommended or used for food processing equipment. Such information should be very important to both design engineer and plant engineer.

If we consider hardness as measured by the Brinell scale as an indication of resistance to abrasive wear, and then tabulate the Brinell hardnesses of the various materials which might be considered for the food processing equipment, we get the following table:

TABLE 2

Material	Brinell Hardness
Stainless Steel (304)	160
Inconel	150
Monel	125
Nickel	100
Nickel-Silver	90
Ingot Iron	90
Cupro-Nickel	80
Copper	30
Aluminum	28
Block Tin	5

Note the comparative high hardness of the stainless steel Type 304 which, when combined with a high strength-weight ratio, indicates a material having excellent resistance to both abrasion and mechanical deformation.

No matter how desirable a material may be from the physical, chemical, and metallurgical aspects, it is no good to the equipment builder unless it is available in the required forms. In spite of the fact that stainless steel is a "Johnny-come-lately" in the materials of construction field, it is now produced in practically every form required for metal fabrication. We are not going to bore you with a list of the available forms but just name any metallic form, be it basic like bars or sheets, or semifabricated like machine screws or ball bearings, and the chances are that it is available in stainless steel.

When we start to talk about initial cost of stainless steel, the management blanches. Yes, it's eight times more expensive than black iron, six times more expensive than galvanized, four times more expensive than copper or aluminum. But when we consider the superior characteristics of the stainless steel in this application, we see that these cost differentials are negligible. Just one day's pack ruined by metal ion contamination would more than equalize the difference in the initial cost of the equipment.

Figures on initial cost of stainless steel are interesting to the equipment builder, and the front office management, but when we talk maintenance cost, it's the plant superintendent and maintenance men who listen. We have already covered the subject of the "clean up" and the ease with which it is accomplished when stainless sanitary equipment is used. This is readily translated into dollars and cents when labor costs for the clean-up crew are examined. And then consider the plant that buys the basic machines and has a maintenance shop with sufficient know-how to do the set up, the piping, and finish installation. Give them a good welding machine, a portable grinder, a pipe thread lathe, a small power brake and the services of an up-to-date stainless steel warehouse, and the installation problem is solved. Furthermore, that maintenance department with the same equipment can revamp the plant almost at will, besides handling all the incidental repairs and day-to-day servicing. From the time of the original installation, stainless equipment is the pride of the maintenance crew.

And last, but not least, we come to the matter of appearance. This may seem trivial, but do you realize that bakeries and bottling plants and dairies have spent literally thousands of dollars on picture windows facing busy streets, just to be able to show the public the gleaming cleanliness of their stainless equipment? Also consider the money spent in the food industry on plant inspection tours, plant movies, color brochures, and other means of impressing the prospective customers with the ultrasanitary conditions under which the plant operates. Certainly the appearance of the equipment is important! The public in general and the housewife in particular has been completely sold on the idea of stainless steel for kitchen utensils, drainboards, sinks, and other equipment. Stainless steel is associated in the mind of Mrs. America with culinary cleanliness and no food processing plant with a wide awake sales or advertising department is going to overlook that fact.

Within the plant itself, there is a psychological importance in the spotless appearance of stainless steel equipment. This hygienic atmosphere impresses upon both employees and management alike, the necessity of maintaining such conditions at all times as a protection for the product. Pride in plant appearance is a prerequisite for securing personnel co-operation in a plant sanitation program.

LITERATURE CITED

1. Clifcorn, L. E., and Peterson, G. T., The retention of vitamin C in tomato juice, Nat. Canners Assoc. *Letters* 1-31-47.
2. Dack, G. M., Food Poisoning, Chicago, University of Chicago Press, 1943.
3. LaQue, F. L., Corrosion resistance of materials for pea, corn, and tomato processing, Internat. Nickel Co. *Tech. Bull.* No. TS 8, 1939.
4. Titus, A. C., Elkins, H. G., Finn, L. T., Fairhall, L. T., and Drinker, C. K., Contamination of food cooked or stored in contact with nickel-chromium-iron alloys, *Journal of Industrial Hygiene*, 1930.
5. Trebler, H. A., Metals and alloys in the dairy industry, *Metals & Alloys*, December, 1940.

DETERGENTS FOR DAIRY PLANTS AND METHODS OF THEIR EVALUATION [1]

H. G. HARDING AND H. A. TREBLER
National Dairy Research Laboratories, Inc., Baltimore 17, Md.

The essential properties of detergents are enumerated. A method is given for calculating formulations of detergents for different purposes, for example, to remove raw milk films, denaturized milk films, milkstone, tarnish, etc.

Tests for certain chemical and physical properties of the detergents under simulated plant conditions are recommended to indicate performance quality of detergents.

In the dairy industry, as in most other food industries, equipment and container cleaning becomes a major part of the operation. All equipment which comes in direct contact with the products has to be completely dismantled, cleaned, and sterilized every day. All containers which are to be re-used must be carefully rinsed, washed, and sterilized after use and before re-use. As much as 50 per cent of the labor cost goes to cleaning in some dairy plants.

Usually the cost of the cleaning powder is only a very small part of the total cost of cleaning. By far the biggest item is labor, and the importance of using the proper cleaning powder, equipment and methods is that a better job can be done with less labor. The best cleaner may be costly per pound but the high cost will usually be more than offset by low labor costs and a good job done.

The present discussion will be limited to the cleaning of dairy equipment and containers which come in direct contact with the products. Consequently the types of soil to be removed are definitely related to dairy products. Of the constituents of milk, the milk sugar is readily soluble in water; the butterfat is fairly easily emulsified or suspended in warm alkaline solutions, but the milk proteins, casein and lactalbumin, may become denaturized by heat, acid, or other means and so become a cleaning problem.

Also milk itself contains calcium and magnesium salts corresponding to a hardness of about 200 grains per gallon (3420 parts per million), and hardness, whether from milk or water, tends to combine with carbonates, silicates, or phosphates in cleaning solutions to form insoluble precipitates. These precipitates may be bound together with protein residues to form milkstone, or with insoluble calcium or magnesium soaps to form scale, especially in soaker-type bottle washers.

Of course there are many types of dirt which are deposited on or in containers used in distributing dairy products. This dirt is usually removed by the cleaning procedures and solutions which are adequate to remove milk residues.

In most cleaning, the action of the detergent solution should be supplemented with some abrasive action, usually from brushes with stiff bristles or from rapidly moving streams of recirculated solutions. There is a strong tendency to eliminate the use of wire-filled brushes, metal sponges, and powdered abrasives for cleaning food handling equipment because of the danger of damage to equipment and of pick up of foreign particles in the product. Brushes with properly-set, stiff, synthetic bristles, such as Nylon, are expensive, but are definitely the most satisfactory and most economical in the long run.

Cleaning, in simple and direct terms, consists of loosening soil and removing it from a surface. Physically and chemically this problem may be quite complex and

[1] Presented before the Seventh Annual Food Conference, Boston, Mass., June 3, 1947.

various efforts have been made to analyze the cleaning problem in a scientific manner. The purpose of such analysis is to attempt to explain the function of various successful cleaning agents and so get information which can be used to develop new and better cleaning agents and cleaning methods.

Thus it has become common to talk about water softening, wetting, peneration, solution, dispersion, emulsification, free-rinsing, etc. as important parts of the cleaning operation; and cleaning mixtures are sought which will give maximum wetting, penetration, solution, etc., of the particular soils which have to be removed from the surfaces to be cleaned. Essentially all dairy cleaning is done with water and the function of the cleaning compounds is to condition the water so that it can do the cleaning job as well as possible with the least possible labor.

With the increase in knowledge about cleaning, our ideas about the composition of the best dairy cleaner continually change. Perhaps the oldest detergent now in use is common soap which, in many ways, is an excellent detergent because it helps wetting, acts as an emulsifying agent for immiscible liquids, and as a dispersing agent for solid particles, but it has the disadvantage that it combines with calcium, magnesium, and metallic ions to form very insoluble, gummy soap compounds. For this reason, soaps are not used for cleaning dairy equipment. However, common soap has been modified chemically so as to form various synthetic compounds which either form relatively soluble compounds or do not form compounds at all with hardness salts. Today, several hundred of these synthetic agents are commercially available. They are organic compounds with fairly large molecules, which have pronounced detergent or wetting characteristics, due to a strong tendency to accumulate at interfaces and thereby to lower surface or interfacial tension. Often these materials assist in emulsification and deflocculation as well as increase the speed of wetting. Here it appears that a compromise has to be made since the speed of penetration of capillary spaces by a liquid is dependent upon the ability to wet the surface, and is directly proportional to the surface tension. However, a wetting agent concentration much greater than that required to wet the surface may reduce the surface tension to such a low value that penetration is delayed. Also, it is possible, for the accumulation of wetting agent at an interface, to delay the dissolving action of the solution. Apparently, much more knowledge is needed about the action of different types of wetting agents in detergent mixtures.

When soap is used, the amount of soap required for cleaning increases with the hardness of the water, and it is found that soap can be saved if hardness is removed by ion exchange with zeolites or by chemical precipitation with soda ash. In the case of chemical precipitation, the gummy precipitate of the insoluble soap is replaced by a dense fine precipitate of carbonate which tends to settle out of the wash solution.

Cleaners containing soda ash or mixtures of soda ash with bicarbonate have long been used in the dairy industry. They were fairly successful because denaturized proteins are soluble in mildly alkaline solutions and because of the water-softening effect of the carbonates in hard waters. However, the carbonate precipitate from hardness has a definite tendency to cause mineral deposits on equipment and containers. It was found that the precipitates produced in hard water by other water-softening alkalies, such as trisodium phosphate or sodium metasilicate, were flocculent and more easily rinsed from equipment. Consequently these alkalies have gradually replaced carbonates in dairy cleaning.

Some of the qualities which presumably make for good cleaning have been evaluated for the four common alkalies, sodium metasilicate, caustic soda, trisodium phosphate, and soda ash. When compared for wetting power they were ranked in the above order *(2)*; for emulsifying power on mineral oil at 100-110° F., the order

was metasilicate and trisodium phosphate first, then caustic soda and soda ash *(9)*; for deflocculating or dirt-suspending power at 0.025% concentration, the order was metasilicate, trisodium phosphate, caustic soda, and soda ash *(2, 5, 9)*. The deflocculating power falls off at higher concentrations. The ability to dissolve milk proteins and other substances depends largely upon the pH and upon the proportion of the total alkalinity which will react with the dirt at that pH. For some soils the minimum effective pH may be about 10, but for milk residues it may be considerably lower, possibly about 8. Metasilicate is effective at pH values up to and including 11.6 and the other three agents at values up to pH 11.

In the practical application of this information to actual cleaning, a compromise is necessary since low concentrations and temperatures just above the melting point of the fat are more effective for emulsification and deflocculation, whereas high concentrations and high temperatures are more effective for dissolving soils.

As long as the only wetting agent available was common soap, and the hardness from the water and soil caused troublesome precipitates with the soap or with common alkalies, dairy cleaning solutions were rather unsatisfactory, especially when used with hard water. However, two relatively recent developments, namely, the commercial availability of synthetic wetting agents at a reasonable price, and the commercial development and availability of calcium sequestering polyphosphates, which keep the hardness salts in clear solution, have made it possible to produce greatly improved cleaning solutions.

Polyphosphates, such as (a) sodium hexametaphosphate, $(NaPo_3)_6$, or Calgon, (b) sodium tetraphosphate, $Na_6P_4O_{13}$, or Quadrafos, (c) sodium triphosphate, also known as sodium tripolyphosphate, $Na_5P_3O_{10}$, and (d) tetrasodium pyrophosphate, $Na_4P_2O_7$, or Pyro, appear to form soluble, surface-active, complex ions or compounds with calcium, magnesium, and various metallic ions, all of which contribute to the so-called hardness of water. The commercial products do not consist of single phosphate compounds but of mixtures whose composition and properties may vary from batch to batch *(3, 4, 8)*. Polyphosphates are not only useful in keeping hardness salts in solution but also aid in emulsification and deflocculation.

The quantities of polyphosphate necessary to prevent turbidity in solutions is dependent not only upon the type of polyphosphate but also upon the concentration and type of alkali (see Fig. 1). While pyrophosphate can be used to prevent turbidity at less than about 12 g.p.g. hardness, the amount required is usually uneconomical, as compared with the amount of Calgon or Quadrafos needed to do the same job.

In general terms, some of the important characteristics of a good dairy cleaner are that it should:

(1) combine with the hardness in the solution to form soluble compounds, from which no precipitation takes place in the presence of carbonates, phosphates, silicates, or soaps (these precipitates, when they form, constitute the major portion of milkstone or waterstone deposits found on dairy equipment),
(2) reduce the interfacial tension between the cleaning solution and the soil and so bring the solution into more intimate contact with the soil,
(3) dissolve milk proteins or other soil, or suspend the soil by emulsification or peptization so that the solution of the cleaner and the dissolved or suspended soil may be readily rinsed free from the cleaned surface,
(4) be low in cost,
(5) be noncorrosive to materials used in the construction of dairy equipment,
(6) be nonpoisonous,
(7) be stable during storage,

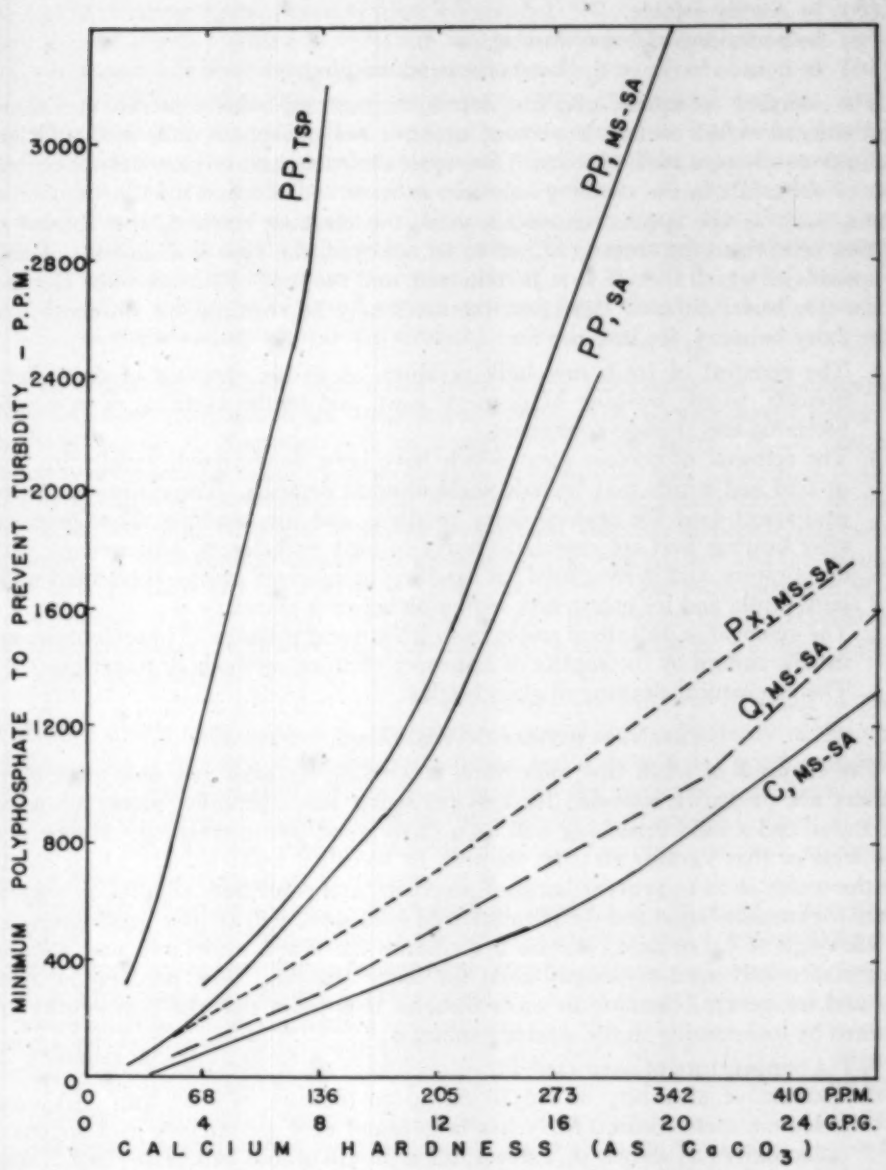


FIG. 1. Relative minimal quantities of commercial polyphosphates necessary to prevent turbidity in weak alkaline solutions.*

* Legend:

PP = tetrasodium pyrophosphate, $Na_4P_2O_7$
Q = sodium tetraphosphate, $Na_6P_4O_{13}$
C = sodium hexametaphosphate, $(NaPO_3)_6$
Px = sodium triphosphate, $Na_5P_3O_{10}$
TSP = trisodium phosphate, 0.25% $Na_3PO_4.12H_2O$ *(6)*
MS-SA = sodium metasilicate, 0.041% $Na_2SiO_3.5H_2O$ + soda ash, 0.041% Na_2CO_3
SA = soda ash, 0.10% Na_2CO_3 *(6)*

(8) be readily soluble,
(9) be noncaking and non-dusting,
(10) be not too harsh on the hands for hand washing.

The simplest adequate alkaline detergent mixture which meets the above requirements would contain a wetting agent, a polyphosphate, and just sufficient alkalinity to dissolve milk proteins. The most desirable and economical concentrations of chemicals in the cleaning solution, as used, will depend upon a number of factors, such as the specific chemicals used, the cleaning method, the volume of solution relative to the amount of soil to be removed, the type and amount of soil, the speed with which the soil is to be removed, and the type of surface to be cleaned.

On this basis, different detergent mixtures may be required for different jobs in the dairy industry, for instance for:

1. The removal of fresh raw milk residues, as in the cleaning of dairy farm utensils, in the washing of farmers' cans, and in the cleaning of raw milk receiving and storage equipment.
2. The removal of protein films which have been denaturized, usually by heat or acid and which may include some mineral deposits. These films occur on equipment used for heating dairy products and for handling these products after heating, and are especially heavy in heat exchangers, pasteurizing vats, evaporators, and in cans used for handling pasteurized cream, condensed milk, buttermilk, and ice cream mix within or between plants.
3. The removal of milkstone and tarnish from metal surfaces. These deposits are usually caused by incomplete or improper cleaning methods or materials.
4. The mechanical cleaning of glass bottles.

CLEANERS PRIMARILY FOR RAW MILK FILMS

The removal of fresh raw milk films is a relatively easy job, and most dairy cleaners are primarily intended for this particular use. Actually, plenty of warm soft water and a mild scrubbing will do a fairly good job of cleaning. Hence it is little wonder that various alkaline, neutral, or so-called acid cleaners which condition the water so as to prevent hardness deposits, and contribute alkalies or wetting agents for emulsification and deflocculation of solid soils, will all give good cleaning.

Although so-called acid cleaners are coming more and more into use, alkaline cleaners are still most commonly used for dairy cleaning. For washing farmers' cans and for general cleaning in wash troughs, it appears that the best results are obtained by maintaining in the washing solution:

(1) a temperature of over 110° F.,
(2) an active alkalinity of 0.03% (a 50:50 mixture of soda ash (SA) and sodium metasilicate (MS) has been found very satisfactory as a source of alkalinity; as shown in Table 1, all soda ash would be cheaper but it does not appear to be as satisfactory as the silicate mixture *(13)*; the cost of trisodium phosphate (TSP) appears far out of line as a source of alkalinity),

TABLE 1

Cost of Alkalinity

	% Active Alk.	Cost per cwt.	1,000 Gals. Solution at 0.03% Active Alkalinity	
			Lbs.	Cost
Soda Ash (Na_2CO_3)	37	$1.05	6.76	$0.071
Metso ($Na_2SiO_3.5H_2O$)	36	2.50	6.95	0.174
TSP ($Na_3PO_4.12H_2O$)	14	2.70	17.87	0.483

(3) a wetting agent concentration (Nacconol NR or equivalent) of 0.008% (80 p.p.m.) (this concentration has been selected because it seems to give maximum benefits at minimum cost),

(4) a hardness sequestering agent concentration adequate to maintain a clear solution in the presence of the total hardness from the water and soil in the washing solution (in order to prevent milkstone formation, it appears safer to sequester the hardness with adequate amounts of polyphosphate rather than to attempt to suspend the precipitate with lesser amounts; as shown in Fig. 3, as soon as the water hardness goes over 6 g.p.g., the sequestering agent is by far the most expensive part of a cleaner; Fig. 3 also shows how much cheaper it is to use zeolite softened water than to use large amounts of sequestering agent in the cleaner).

The following example shows one method for calculating an approximately correct cleaner composition for specific conditions. The wetting agent should be about 80 p.p.m. of Nacconol NR, or equivalent wetting agent. If an adequate hardness sequestering agent concentration is contemplated and Quadrafos is to be used, a Quadrafos concentration about 8 times the calcium concentration, or about 3.2 times the total hardness, expressed as p.p.m. calcium carbonate, should be adequate. Thus, if the hardness of the water is 5 g.p.g. (85 p.p.m.) and the hardness from milk residues is estimated at 2 g.p.g. (34 p.p.m.), the total hardness in the wash solution will be 7 g.p.g. (119 p.p.m.). The polyphosphate concentration in the wash solution to sequester this hardness will be calculated at 3.2 times 119, or 381 p.p.m. of Quadrafos.

The next problem is to determine the concentration and type of alkali or blend of alkalies which must be used to supply the required active alkalinity of the wash solution. A 1:1 mixture of sodium metasilicate and soda ash is a good economical source of buffered alkalinity for can washing when the hardness is properly eliminated or sequestered. A concentration of 0.02-0.03% (200-300 p.p.m.) active alkalinity is adequate for washing farmers' cans, and cleaning raw milk equipment and for general cleaning in wash troughs.

The active alkalinity of the 1:1 mixture of MS and SA is (36 + 37) /2 or 36.5% as NaOH. The wash solution at 0.03% active alkalinity will contain 300 p.p.m. NaOH equivalent. This would be supplied by 300/.365, or 822 p.p.m. of the 1:1 mixture of MS and SA, or 411 p.p.m. of each.

Consequently, the wash solution will contain:

Wetting agent (Nacconol NR)	80 p.p.m.
Polyphosphate (Quadrafos)	381 p.p.m.
Sodium Metasilicate (Metso)	411 p.p.m.
Sodium Carbonate (Soda Ash)	411 p.p.m.
Total Washing Powder (which corresponds to a concentration of 0.128%)	1283 p.p.m.

Since 1283 p.p.m. represents 100% of the cleaning powder, the composition of the powder in percent would be:

Nacconol (80/1283), × 100, or 6.3%; Quadrafos (381/1283) × 100, or 29.7%; Metso and Soda Ash each (411/1283) × 100, or 32.6%.

This powder at 0.13% concentration (less than 17.5 ounces per 100 gallons of washing solution) will prevent precipitation from a total hardness of 7 g.p.g. and give an active alkalinity of 0.03%.

The above method of calculating cleaning powder compositions can be used for any desired conditions.

In Fig. 2 is shown how the composition of the cleaning solution would vary so as to meet the above requirements for any hardness up to 25 g.p.g. In Fig. 3 is shown how the cost in dollars per 1,000 gallons of the cleaning solution varies with the hardness. Also shown is the influence of the hardness on the cost of the various constituents. The variation in cost of zeolite softening with hardness is shown as a triangular wedge between the dotted and dashed lines. This, compared with the

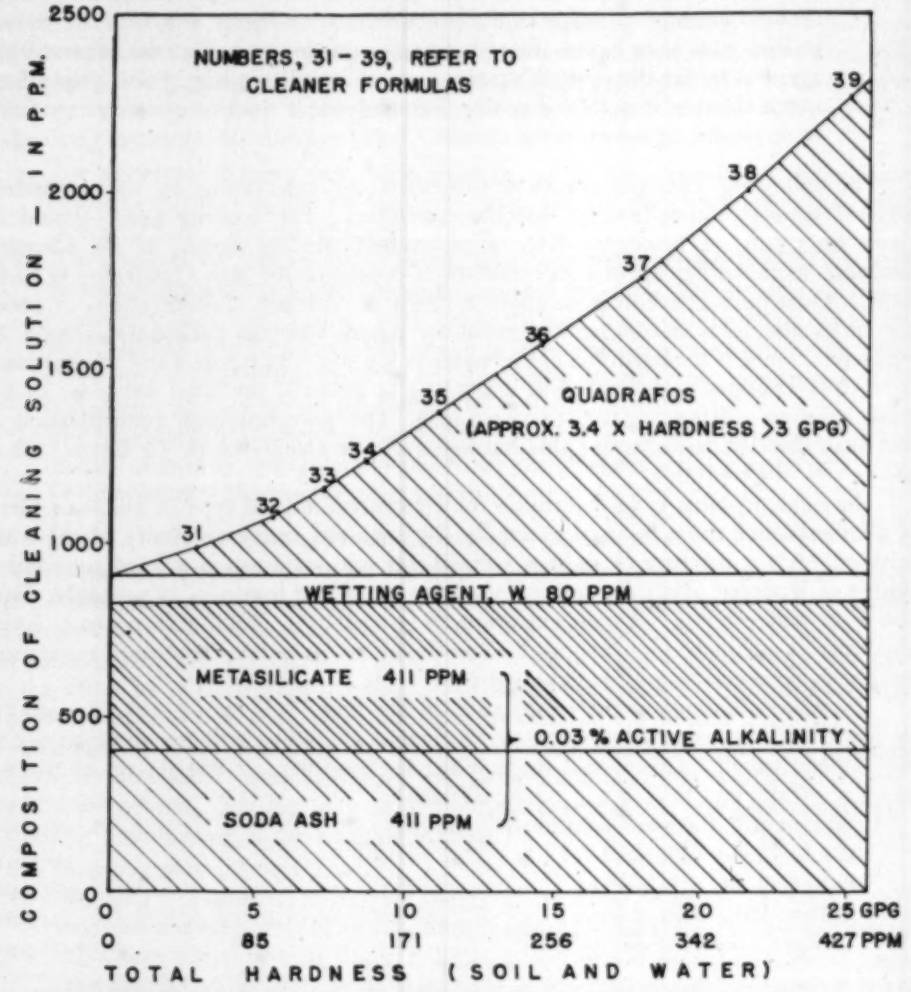


FIG. 2. Influence of hardness on the composition of recommended cleaning solutions.

cost of hardness sequestering agent, Quadrafos, graphically emphasizes the fact that 10,000 grains of hardness can be removed by zeolite softening for about 5 cents while, to sequester this same amount of hardness with polyphosphate would cost more than 40 cents. Of course, these costs are not directly comparable because, in the case of the polyphosphates, only the actual cleaning solution is softened, while in the case of the zeolite treatment the rinse water is also softened. It would probably not be necessary, however, to use 7 times as much rinse water as wash solution.

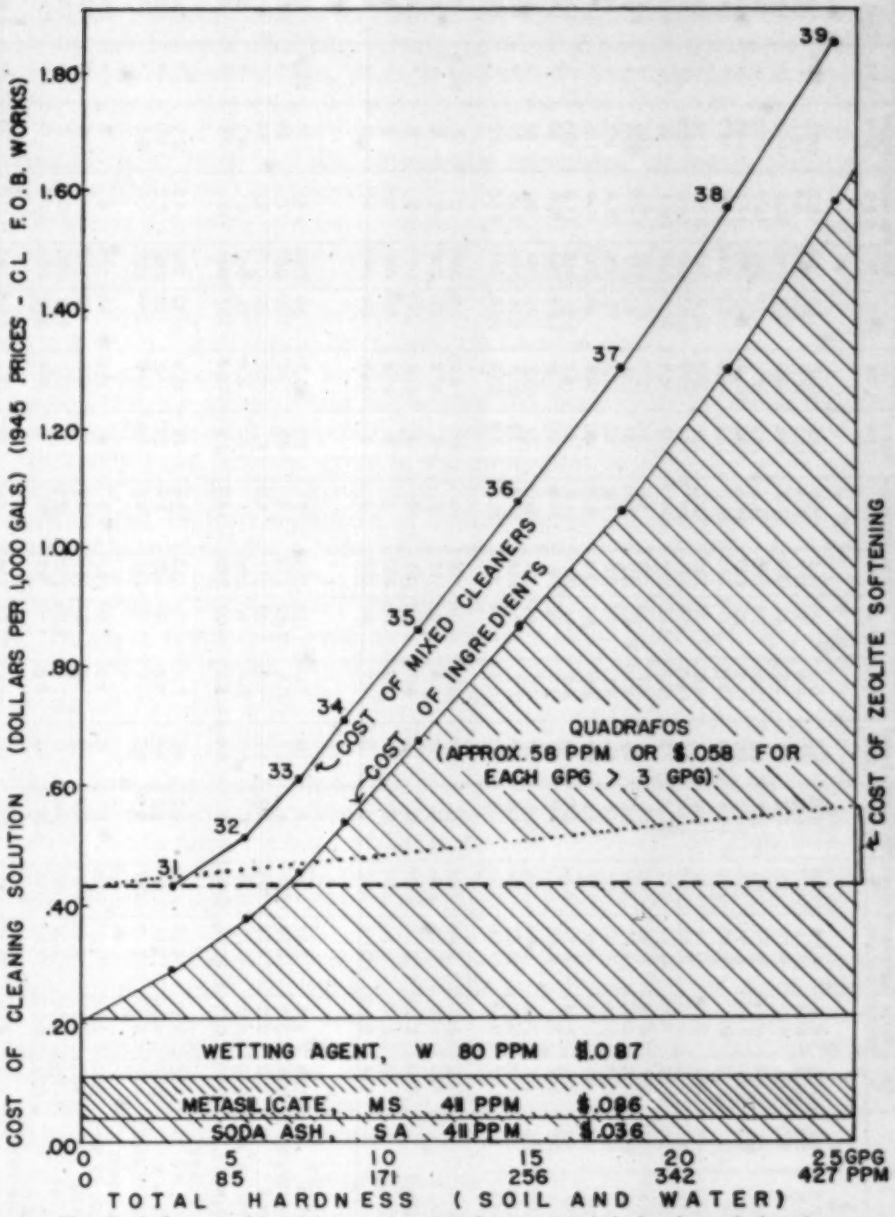


FIG. 3. Influence of hardness on the cost of recommended cleaning solutions.*

There are hundreds of dairy cleaners on the market but most of them only supply alkalinity and soften the water by precipitation. In some, a wetting agent or a calcium sequestering phosphate, or both, have been added, but rarely in the most desirable balance, even for a limited range of hardness conditions. Also, there frequently appears to be an excessive spread between the estimated cost of ingredients and the selling price. This may be justified by the large amount of service the industry demands and gets from suppliers of cleaning materials. The third part of Table 2 gives data on some commercial alkaline cleaners.

* Numbrs 31-39 refer to specification cleaner formulas.

TABLE 2

Comparison of Alkaline Dairy Cleaners

	Composition %				Active Alk. %	Approx. Price per cwt.	Estimated Cost of Ingredients per cwt.	Solution at 0.03% Active Alk.					Solution at 0.05% Active Alk.					Solution at 0.25% Conc.				
								Conc. %	For Hardness gpg	Wetting Agent ppm	For 1,000 Gals. Lbs.	Cost	Conc. %	For Hardness gpg	Wetting Agent ppm	For 1,000 Gals. Lbs.	Cost	Active Alk. %	For Hardness gpg	Wetting Agent ppm	For 1,000 Gals. Lbs.	Cost
I. SPECIFICATION CLEANERS	SA	MS	Q	W																		
31	41.8	41.8	8.3	8.1	30.5	$5.11	$3.53	.099	3.0	80	8.3	$.43	.164	4.5	133	13.7	$.70	.076	6.5	202	20.8	$1.06
32	38.6	38.5	15.4	7.5	28.2	5.78	4.19	.107	5.5	80	8.9	.51	.177	7.9	133	14.7	.85	.070	9.8	187	"	1.20
33	35.8	35.7	21.5	7.0	26.1	6.35	4.76	.115	7.2	80	9.6	.61	.192	10.3	134	16.0	1.02	.065	12.5	175	"	1.32
34	33.4	33.4	26.7	6.5	24.4	6.84	5.25	.123	8.7	80	10.3	.71	.205	12.8	133	17.1	1.17	.061	14.7	162	"	1.42
35	30.1	30.1	34	5.8	22.0	7.52	5.90	.137	11.2	80	11.4	.86	.227	16.2	132	18.9	1.42	.055	17.7	145	"	1.56
36	26.5	26.4	42	5.1	19.3	8.27	6.65	.156	14.6	80	13.0	1.08	.259	21.7	132	20.6	1.79	.048	21.6	127	"	1.72
37	23.5	23.5	48.5	4.5	17.1	8.87	7.17	.175	18.0	79	14.6	1.30	.292	25.2	131	24.3	2.16	.043	23.0	112	"	1.85
38	20.6	20.6	54.8	4.0	15.0	9.47	7.83	.200	21.6	80	16.7	1.58	.333	29 ?	133	27.7	2.63	.037	24.6	100	"	1.97
39	18.2	18.1	60.2	3.5	13.2	9.80	8.33	.227	25.1	79	19.0	1.86	.379	34 ?	132	31.5	3.09	.033	26.1	87	"	2.04
51	44.7	44.7	5.4	5.2	32.7	4.48	2.91	.092	2.2	48	7.7	.35	.153	3.0	80	12.75	.57	.081	4.5	130	"	0.93
52	42.5	42.5	10.1	5.0	30.9	4.95	3.37	.097	3.6	49	8.1	.40	.162	5.5	81	13.5	.67	.077	7.7	125	"	1.03
53	40.4	40.3	14.6	4.7	29.4	5.38	3.80	.102	5.0	48	8.5	.46	.170	7.2	80	14.2	.76	.073	9.4	117	"	1.12
54	38.5	38.5	18.5	4.5	28.1	5.76	4.17	.107	6.3	48	8.9	.51	.178	8.7	80	14.8	.85	.070	11.4	112	"	1.20
55	35.8	35.7	24.3	4.2	26.1	6.33	4.73	.115	8.0	48	9.6	.61	.192	11.2	81	16.0	1.01	.065	13.8	105	"	1.32
56	32.5	32.5	31.2	3.8	23.7	7.01	5.40	.127	10.0	48	10.6	.74	.211	14.6	80	17.6	1.23	.059	16.4	95	"	1.46
57	29.8	29.8	36.9	3.5	21.7	7.56	5.94	.138	12.1	48	11.5	.94	.231	18.0	81	19.3	1.46	.054	19.0	87	"	1.57
58	27.0	26.9	43.0	3.1	19.6	8.15	6.52	.153	14.4	47	12.7	1.04	.255	21.6	79	21.3	1.74	.049	21.5	77	"	1.70
59	24.3	24.3	48.5	2.8	17.7	8.69	7.06	.170	17.2	48	14.2	1.23	.283	25.1	79	23.6	2.05	.044	23.0	70	"	1.81
II. STRAIGHT CHEMICALS																						
CAUSTIC SODA	98 NaOH				98.0	2.80	2.50	.031	0	0	2.6	.073	.051	0	0	4.25	.119	.245	0	0	20.8	.58
SODA ASH	99 Na_2CO_3				37.0	1.35	1.05	.081	0	0	6.8	.092	.135	0	0	11.2	.151	.092	0	0	"	.28
METSO	$Na_2SiO_3.5H_2O$				36.0	2.80	2.50	.083	0	0	6.9	.217	.139	0	0	11.6	.325	.090	0	0	"	.58
TSP	$Na_3PO_4.12H_2O$				14.0	2.90	2.70	.214	0	0	17.8	.516	.357	0	0	29.8	.865	.035	0	0	"	.60
BORAX	$Na_2B_4O_7.10H_2O$				17.4	2.80	2.08	.172	0	0	14.3	.40	.288	0	0	24.4	.68	.043	0	0	"	.58
III. COMMERCIAL CLEANERS																						
A. Complete Cleaners — Reasonably Priced																						
1	SA 55, MS 35, Px 8, W 2				32.9	3.75	2.67	.091	2	18	7.6	.29	.152	3	30	12.7	.48	.082	4	50	20.8	.78
2	SA 15, MS 30, TSP 30, PP 10, Px 10, W 2				21.9	5.75	3.36	.137	4	27	11.4	.66	.228	6	45	19.0	1.09	.055	7	50	"	1.20
3	SA 5, MS 76, Px 16, W 3				29.2	5.70	4.26	.103	4.8	31	8.6	.49	.171	6.4	51	14.3	.82	.073	8.1	75	"	1.19
4	SA 50, MS 7, TSP 10, PPa 28, W 5				24.8	4.50	3.17	.121	5	60	10.1	.46	.202	7	101	16.8	76	.062	8	125	"	.93
5	SA 5, MS 52, Px 40, W 3				20.6	8.75	6.54	.146	10	44	12.2	1.07	.243	14.6	73	20.2	1.77	.051	15	75	"	1.82
B. Complete Cleaners — High Priced																						
6	SA 23, MS 63, PPa 13, W 5				32.8	9.25	4.35	.092	2.2	46	7.7	.71	.153	3.4	76	12.8	1.42	.082	4.5	125	"	1.92
7	CS 15, SA 61, PPa 15, W 2				37.0	9.00	2.11	.081	2.2	16	6.8	.61	.135	3.4	27	11.2	1.02	.092	5.0	50	"	1.87
8	SA 45, MS 5, TSP 20, PP 25, W 5				23.7	8.00	3.18	.127	4.4	63	10.6	.85	.211	6.2	106	17.6	1.41	.059	7.0	125	"	1.67
C. Cleaners Lacking Wetting Agent																						
9	CS 10, SA 70, TSP 10, PP 10				33.1	7.44	1.81	.091	2	0	7.6	.57	.151	3	0	12.6	.94	.083	4	0	"	1.55
10	SA 5, MS 80, PPa 15				32.1	3.45	2.88	.094	2.7	0	7.8	.27	.156	3.7	0	13.0	.45	.080	4.9	0	"	0.72
11	MS 35, TSP 20, PP 45				19.9	9.50	3.92	.151	7.6	0	12.6	1.20	.252	10.0	0	21.0	1.99	.050	10.0	0	"	1.98
12	CS 5, MS 55, Q 40				25.2	12.00	7.90	.118	14	0	9.8	1.18	.199	20	0	16.6	1.99	.063	22.7	0	"	2.50
D. Cleaners Lacking Polyphosphate																						
13	SA 47, TSP 50, W 3				24.4	9.23	2.23	.123	0	37	10.3	.95	.205	0	61	17.1	1.58	.061	0	75	"	1.92
14	TSP 96, W 4				13.2	9.50	3.09	.226	0	90	18.8	1.79	.376	0	149	31.3	2.98	.033	0	100	"	1.97
E. Cleaners Lacking Wetting Agent and Polyphosphate																						
15	SA 60, TSP 40				27.8	2.50	1.71	.108	0	0	9.0	.23	.180	0	0	15.0	0.38	.069	0	0	"	.52
16	SA 53, TSP 47				26.2	4.55	1.83	.155	0	0	9.6	.44	.191	0	0	15.9	.72	.065	0	0	"	.98
17	SA 61, SO 39, M 11				29.6	4.20	1.16	.133	0	0	11.1	.47	.222	0	0	18.5	.78	.080	0	0	"	.97

Since the available commercial cleaners did not seem to provide the most desirable balance between alkalinity, wetting power, and polyphosphates, a series of nine specification cleaners (Nos. 31 to 39 in Table 2) was formulated to cover the hardness range up to 25 g.p.g. In order to meet the New York City health department requirement of 0.05% active alkalinity for can washing, a special series of cleaners (Nos. 51 to 59 in Table 2) was also formulated for use in plants which come under New York City inspection.

The idea of a cleaning solution containing alkalinity, wetting agent, and hardness sequestering agent has actually been used for more than ten years in some of our plants. Balanced compositions to meet specific conditions, mixed and packed specifically for us by chemical jobbers, have been used for about four years. Such cleaners are now being used in more than two hundred plants.

These specification cleaner mixtures may not give the very best nor the most economical cleaning solutions that can be obtained, but they do appear to represent a great advance over what was previously used.

The specification formulas given in the upper part of Table 2 can be used in various ways, either for the purpose of telling the manufacturer exactly the cleaning mixture desired, or for the purpose of mixing cleaners in the milk plant as dry mixtures or as stock solutions. Also various combinations are possible; for instance, it would be possible to buy a basic formula from the manufacturer and add a suitable amount of sequestering phosphate to take care of the difference in hardness for any plant. However, under most conditions it has been found practical to buy complete mixtures, in spite of the fact that considerable savings can be made in direct chemical cost by purchasing chemicals and making stock solutions.

FARM CLEANING MIXTURES

The specification cleaners listed above were developed primarily for use in can washing and plant cleaning. They are also being used very successfully by milk producers on the farm for hand washing utensils. However, they do give wash solutions with rather high pH, about 10.8, or higher, which may be irritating to the skin. For this reason, it may be advisable to change the composition of farm cleaners so as to get a lower pH.

A 1:1 mixture of soda ash and sesquicarbonate used for alkalinity, instead of the standard 1:1 mixture of soda ash and metasilicate, will give a pH of about 10 in the wash solution. Borax, or a mixture of borax with 5% soda ash used for alkalinity, will give a pH of about 9. For farm cleaning, the tendency is definitely towards the complete elimination of special alkalinity producing salts and of cleaners which contain only a calcium sequestering agent (Quadrafos) and a wetting agent. These will give a pH of about 8 in the wash solution.

CLEANERS FOR DENATURIZED MILK FILMS

Milk films, which contain denaturized proteins and precipitated mineral salts, are not completely dissolved by conditioned water alone. As seen in Table 3, the composition of these milk films varies greatly with the conditions of formation *(12)*. Probably, milk films in pasteurizing vats are similar to the laboratory sample, No. 1, while films in regenerative heat exchangers may be similar to the filter frame sample, No. 4.

The calcium and magnesium from the milk films can be sequestered or dissolved with polyphosphate. Since it requires considerably more polyphosphate to solubilize calcium from a precipitate than from a solution, about 4.8 pounds of Quadrafos or Calgon might be required for each pound of hardness expressed as $CaCO_3$. The

TABLE 3

Analyses of Milk Coatings Obtained From Plant Equipment and From A Laboratory Experiment [a]

Composition [b]	Milk Coating Samples From			
	Sample No. 1	2	3	4
	Laboratory sample	Barrel heater	Tubular heater	Filter frame
	%	%	%	%
Protein	71.6	41.1	30.3	17.2
Ash	8.4	11.9	46.6	64.6
Ash constituents:				
Ca as $CaCO_3$	68.5	70.3	82.9	85.1
Mg as $CaCO_3$	4.2	3.1	1.3	10.6
CO_2 as $CaCO_3$	0.0	46.3	0.1	1.9
P_2O_5	41.4	42.2	20.7	27.7
Total hardness as $CaCO_3$	6.1	8.7	39.2	62.3

[a] Recalculated on a moisture-free basis from Parker and Johnson *(12)*.
[b] All samples free from traces of lactose.

protein can be dissolved in alkali and, at pH 10.9, might require about 6.5 pounds of active alkalinity for 100 pounds of protein. For a film like No. 1, the ratio of Quadrafos to active alkalinity would then be about 6:1, and for a film like No. 4, the ratio would be about 270:1. Thus, an alkaline cleaner with polyphosphate, which, at a given concentration and volume of solution, would be just adequate to dissolve a given weight of milk film, No. 1, would have to be used at more than 45 times that concentration to remove the same weight of a No. 4 film. With an insufficient amount of polyphosphate, the mineral deposit will not be completely removed and the tendency will be to leave milkstone on the equipment.

An alternate procedure has been used for many years. It is a two-stage cleaning process employing, first, a weak acid solution, such as 1% H_3PO_4 or equivalent, to dissolve the mineral deposits from the film, then, a rinse to remove loosened soil and excess acid, and then, an alkaline polyphosphate solution to dissolve proteins, neutralize residual acid, and prevent hardness precipitation. This is still the preferred procedure for heavy deposits but, for somewhat lighter deposits, the one-stage process with high concentrations of polyphosphate may be more economical. The balance between the active alkalinity polyphosphate, and wetting agent, which is most economical for removing raw milk films, is usually quite different from that required for removing heavy films of denaturized protein. For removing films from pasteurizing vats, a solution containing 2500 p.p.m. polyphosphate (Quadrafos), 1700 p.p.m. wetting agent (Nacconol NR), and 950 p.p.m. each of soda ash and sodium metasilicate has given good cleaning when applied with a stiff brush. Specification cleaner 38, supplemented with wetting agent, is satisfactory.

For cleaning by recirculation, enough of the regular cleaner might be used to supply the required active alkalinity (often 0.03-0.06%), the wetting agent, and part of the polyphosphate. The remainder of the polyphosphate, usually 1-5 lbs. of Quadrafos per 100 gallons, can be supplied by direct addition to the solution.

If the soil is very heavy, it is advisable to scrape, brush, and rinse away as much of the loose material as possible before using a cleaning solution.

REMOVING MILKSTONE AND TARNISH

If cleaners containing adequate amounts of polyphosphate are used, the formation of milkstone and tarnish will not occur, except possibly where the rinse water is exceptionally hard.

In the past, where milkstone did occur, abrasive cleaners, together with metal sponges, have helped remove these deposits mechanically, but this treatment was time-consuming and often damaged the equipment.

If the equipment surface will permit, the simplest method of removing milkstone is to scrub the mineral portion with warm acid solution, then rinse, and scrub again with a warm alkaline polyphosphate solution to remove any residual protein, fat, or acid. Phosphoric acid in about 1% solution is satisfactory for the acid solution. Other acids and acid salts, such as hydroxyacetic acid and sodium acid sulfate (niter cake), can also be used but apparently require considerably higher concentrations than what would be chemically equivalent to 1% phosphoric acid, in order to give the same lime dissolving power. Wetting agents do not seem to be beneficial in these acid solutions.

BOTTLE WASHING SOLUTIONS

In the cleaning of glass milk bottles in soaker-type bottle washers, there is no contact of the hands with the cleaning solution, so that strong alkalies such as caustic soda can be used. In many locations the composition and concentration of the cleaning solution, as well as the temperature of the solution, are subject to health department regulations. A mixture containing mainly caustic soda, with small amounts of polyphosphate, such as 1-10 lbs. of tetrasodium pyrophosphate, and of wetting agent, such as 1-3 lbs. of Nacconol NR or equivalent, to each 100 lbs. of caustic has proven very satisfactory. The caustic dissolves the soil, saponifies the butterfat, and acts as a germicide. For reasons of economy, the concentration and temperature used should be the lowest that give satisfactory cleaning and sterilizing, but, of course, not lower than local regulations permit. It should be noted that caustic has some etching effect on glass, especially on applied color lettering.

Pyrophosphate is used to disperse solid soils and insoluble soaps, and too high a concentration may clean the bottle carriers so well that bottles stick in the pockets. Consequently, in washers with gravity discharge, it is desirable to use the maximum amount of pyro which will still allow satisfactory bottle discharge. The wetting agent reduces surface tension, gives more rapid and complete drainage, and so reduces carry-over and loss of wash solution. Wetting agents also aid in emulsification and peptization. Their presence is especially beneficial in freshly prepared bottle washer solutions before soaps have been formed from the butterfat from the soil.

METHODS OF TESTING CLEANERS

So far no really satisfactory method is available for testing the detergency of solutions for cleaning dairy equipment. For the appraisal of detergents we have to rely on actual use-tests in the plant, or on laboratory tests which simulate actual use-tests, or on indirect laboratory tests of certain properties which presumably contribute to good cleaning action.

Evaluation by actual use is not a satisfactory method of comparison, due to difficulties in standardization and measurement of soil quantity, cleaner concentration, and cleanliness of equipment. Where hand scrubbing is necessary, comparisons are particularly difficult because of the impossibility of standardizing the operators' physical effort and mental attitude, which may vary from day to day and from hour to hour. Actually, the cooperative attitude of the worker may easily become the most important factor, and quite beyond practical experimental control. Failure to follow the prescribed methods of cleaning may result in improper cleaning and in blaming the cleaning methods and materials for the failure. Then there is a tendency to make new methods or materials work, or appear to work, satisfactorily, especially if the promoter of the novelty is enthusiastic and is present during the test. If use-

tests must be relied upon they should be continued for at least one week, and often for a longer time, in order to get dependable comparisons. During this time, the supervisory personnel should make sure that the method and materials are being used as intended, but otherwise be careful to refrain from unduly influencing the operator towards a biased attitude.

The interest or partiality displayed by a supervisor at the time comparative cleaning tests are being made may be extremely important. Conditions are usually made ideal for the use of the new material or method, and the results obtained are often compared with routine results with the previous method or material used. Knowing that management is interested may easily stimulate the worker to do a better and more complete cleaning job with whatever method or material management appears to be interested in.

Many types of laboratory tests have been devised to simulate actual use-tests. These depend upon the preparation of standard soils, their application to standard test pieces, the cleaning action of a standardized cleaning solution, with or without standardized mechanical scrubbing, either for a standard period of time or until the surface appears to be cleaned, and a standard method of judging the residual soil remaining on the test surface. Much work has been done in applying this type of test to textile cleaning *(1, 14)*. While considerable progress has been made in applying this test to cleaning hard surfaces, such as metal and glass, the results do not appear entirely satisfactory.

The evaluation of the amount of soil on test pieces by optical methods based on light transmission or light scattering by films (deposited on glass plates), interposed in a beam of light, has been used by several investigators *(7, 11, 15)*. However, films on dairy equipment are not usually on glass but on metal, and also may be quite thick, even several times the thickness required to make the test piece opaque.

Until such time as satisfactory laboratory methods for actually measuring the detergent effect are developed, it appears necessary to measure certain properties of the cleaning solution, which seem to be more or less directly related to their detergency. For routine work on alkaline dairy cleaners, the determination of alkalinity, pH, surface tension, turbidity preventing power, and P_2O_5 from ortho and total phosphates, will at least give the buyer a good check on whether or not he is getting what he is paying for.

Alkalinity determined by titration to the phenolphthalein and methyl orange end-points, and expressed as equivalent NaOH, is referred to as active and total alkalinity. This is expressed on the basis of the cleaning solution and of the dry cleaner mixture. Active alkalinity appears to be a rough measure of the amount of protein which can be dissolved, while pH is a rough measure of the rate of dissolving proteins.

pH can best be determined with a special high alkali glass electrode for solutions of suitable concentrations. For simplified tests, the colorimetric method can be used.

Surface tensions by the DuNouy method can be determined at room temperature for these same concentrations. The surface tension of the cleaning solution may not be directly related to detergency by any known simple formula, but all the organic detergents and wetting compounds used in cleaner mixtures are surface active in some way and, consequently, the fairly simple measurement of surface tension becomes a convenient method of checking up on a cleaner to see how much of a given surface active compound it contains.

As mentioned above, polyphosphates in alkaline solution have the ability to prevent the appearance of turbidity and precipitation due to the formation of insoluble compounds from dissolved calcium and magnesium hardness salts with

alkalies. Several methods have been developed for testing this turbidity preventing power of polyphosphates in cleaner mixtures *(6, 10)*. In the test preferred by us, an amount *A* of stock cleaner solution is rapidly mixed with an amount *B* of diluted calcium solution, and observed for the appearance of turbidity at room temperature and after holding for various lengths of time in a water bath at higher temperatures. The amount *A* of stock cleaner solution is selected so as to give in the mixture, *A* plus *B*, either a certain active alkalinity, such as 0.03 or 0.05 percent, or a certain concentration, such as that specified by a cleaner manufacturer for use. The amount *B* is chosen so as to make *A* plus *B* equal to 50 ml., and is made up of an amount of stock calcium solution *C*, plus distilled water. For each sample, a series of tubes is made up with varying amounts of calcium solution, such that the calcium hardness in the mixture, *A* plus *B*, varies in small known steps, for instance, 1 g.p.g. Observations are made to determine the highest calcium hardness at which *no* turbidity appears, and the lowest calcium hardness at which the *faintest trace* of turbidity appears.

Preferably, the holding time and temperature should be selected so as to cover the worst conditions to which the cleaning solution is subjected in actual use. In milk-can washers this might be about 158° F. (70° C.) for 90 minutes, and this has been used by us. The use of a stock calcium chloride solution, the calcium content of which is equivalent to 855 p.p.m. (50 g.p.g.) $CaCO_3$, is convenient since 1 ml. in 50 ml. gives 1 g.p.g. hardness. Usually a 1% solution of cleaner is satisfactory. It is important, in this test, to mix the diluted hardness solution very rapidly with the stock cleaner solution, so that the faint flash turbidity, which forms at first, is brought into contact with polyphosphate for solution, before an appreciable increase in size of the insoluble particles takes place. As aids in recognizing faint turbidities, a black background, and observation lengthwise of the sample tube, in direct comparison with control tubes of cleaner without hardness and of distilled water, are important.

As pointed out earlier, it appears to be better to keep turbidity from hardness salts from forming in the cleaning solution than to attempt to disperse these insoluble particles. Accordingly, this test has been used to evaluate various cleaners, that is, to show what concentrations are necessary to prevent turbidity at various hardness levels.

If a cleaner contains only one polyphosphate, it is theoretically possible to estimate the polyphosphate on the basis of the turbidity prevention test and of the P_2O_5 other than ortho. This does not always work out in practice, due to deterioration of the cleaner mixture in storage.

DETERIORATION IN STORAGE

An important consideration in the interpretation of analytical data on detergents is the effect of storage conditions and time upon the original ingredients. The common alkalies may be regarded as combinations of sodium oxide with weak acids. Thus 2 NaOH might be regarded as $Na_2O \cdot H_2O$; Na_2CO_3 as $Na_2O \cdot CO_2$; 2 $NaHCO_3$ as $Na_2O \cdot 2\ CO_2 \cdot H_2O$; Na_2SiO_3 as $Na_2O \cdot SiO_2$; and 2 Na_3PO_4 as 3 $Na_2O \cdot P_2O_5$. For example, anhydrous Na_2O, exposed to moist air, is changed to caustic soda, which, on further exposure to carbon dioxide in the air, is changed to sodium carbonate (soda ash), and, on still further exposure to carbon dioxide, is changed to sodium bicarbonate. Exposure of sodium metasilicate to moisture and carbon dioxide tends to give insoluble silica and sodium carbonate which may show further change to bicarbonate. Such deteriorating changes reduce the pH and active alkalinity (to phenolphthalein), but do not change the total alkalinity (to methyl

orange), when correction is made for increased weight due to moisture and carbon dioxide.

The polyphosphates are often used in the form of anhydrous salts which are hygroscopic. In the concentrated solution on the surface of the polyphosphate particle, the presence of moisture, carbon dioxide, and alkali from nearby particles tends to cause a gradual reversion to simpler polyphosphates and to orthophosphate. Consequently, alkaline polyphosphate mixtures are not stable under ordinary conditions of storage.

The stability of synthetic wetting agents, when stored in combination with polyphosphates and alkalies, depends upon the type of wetting agent. In some cases, the deterioration may be quite rapid, in other cases, no serious change appears, even after several months storage.

For these reasons, the interpretation of analytical results should take into account the previous history of the sample.

COMPOSITION AND COMPARISON OF SOME COMMERCIAL ALKALINE DAIRY CLEANERS

Comparative data are given in Table 2 for two series of specification cleaners and some common commercial alkaline cleaners. It is apparent from this table that usually the most economical cleaning can be obtained by using specification cleaners.

Cleaning powders can be compared on the basis of:

1. The ingredient cost and the spread between that cost and the selling price. Of course, this spread, besides profit, includes the cost of freight from chemical works to the blending plant, the cost of handling, mixing, packaging (the cost of the container), and rehandling for shipment, as well as factory overhead and selling expense, which, with most commercial cleaners, also includes the very considerable costs of service in demonstrating the cleaning procedures to customers.

In 1945 a spread of 1.3 to 1.7 cents per pound appeared ample to cover profit and the costs from chemical works to the packaged specification cleaner ready for shipment, but not including the cost of customer service. Now the spread might be 50 per cent greater.

2. The active alkalinity, from which can be calculated the pounds of powder required to give a certain alkalinity in a certain number of gallons of cleaning solution.

In Table 2, data are given for each cleaner in three solutions: (a) at 0.03% active alkalinity, which is satisfactory and is recommended for washing of farmers' cans and for general cleaning, (b) at 0.05% active alkalinity, which is required by the New York City health department for can washing, and (c) at 0.25% concentration, which has been widely advocated by commercial cleaner firms.

3. The maximum hardness (as $CaCO_3$ in grains per gallon), which the cleaner, at the stated concentration, will maintain in clear solution at 158°F. (70°C.) for 90 minutes. This is a measure of the milkstone preventing ability under severe conditions of use.

4. The wetting agent concentration expressed in p.p.m., disregarding the important fact that various wetting agents have very different surface tension lowering effects.

5. The pounds of cleaner required and the cost for 1000 gallons of solution at the stated concentrations. Because of the many factors mentioned above, the costs given per 1000 gallons of solution are, of course, applicable only with qualifications.

In Table 2, a number of widely-used, commercial, alkaline dairy cleaners have been arranged in 5 groups:

Group A includes cleaners which provide both polyphosphate and wetting agent, and which appear to be reasonably priced.

Group B also includes cleaners which provide both polyphosphate and wetting agent, but which appear to have an excessive spread between the cost of ingredients and the selling price.

Group C includes those cleaners which provide polyphosphate but lack wetting agent.

Group D includes those cleaners which provide wetting agent but lack polyphosphate.

Group E includes commonly used dairy cleaners which provide neither wetting agent nor polyphosphate.

It will be noted that many commercial cleaners are lower in wetting agent than we, at the present time, think they should be.

SUMMARY

Alkaline detergent mixtures for dairy plants have been considered on the basis that they should provide adequate polyphosphate to keep hardness salts in solution, adequate synthetic wetting agent for ease of contact, and adequate active alkalinity to dissolve denaturized protein residues. On this basis a method is given for calculating compositions for specific conditions. Cleaning solution compositions for O — 25 g.p.g. hardness are shown graphically and two series of nine specific cleaner mixtures, developed from this graph, are given.

Since satisfactory comparison of dairy cleaners cannot be obtained by either actual use-tests in the plant, or by laboratory tests which simulate actual use-tests, the best available basis for a fair evaluation appears to be given by tests for pH, alkalinity, surface tension, and turbidity preventing power under simulated plant conditions. Such data have been used to compare specification cleaners, common alkalies, and representative common commercial cleaners.

LITERATURE CITED

1. Appel, W. D., Smith, W. C., and Christison, Hugh., Am. Dyestuff Rept. *17*, 679-83 (1928).
2. Baker, C. L., Ind. Eng. Chem. *23*, 1025-32 (1931).
3. Bell, R. N., Ind. Eng. Chem., Anal. Ed., *19*, 97-100 (1947).
4. Bell, R. N., Ind. Eng. Chem., *39*, 136-40 (1947).
5. Fall, P. H., J. Phys. Chem., *31*, 801-49 (1927).
6. Gilmore, B. H., Ind. Eng. Chem., *29*, 584-90 (1937).
7. Hughes, R. C., and Bernstein, Rubin., Ind. Eng. Chem., *37*, 170-75 (1945).
8. Jones, L. T., Ind. Eng. Chem., Anal. Ed., *14*, 536-42 (1942).
9. Johnson, A. H., Ann. Rept. New York State Assoc. of Dairy and Milk Inspectors *6*, 37-46 (1932).
10. Mann, E. H., and Ruchhoft, C. C., U. S. P. H. S., Pub. Health Repts., *61*, 539-45 (1946).
11. Ibid., *61*, 877-87 (1946).
12. Parker, M. E., and Johnson, A. H., Proc. Internat. Assoc. Milk Dealers, Plant Sec., *23*, 5-14 (1930).
13. Vail, J. G., Ind. Eng. Chem., *28*, 294-99 (1936).
14. Vaughn, T. H., Vittone, Jr., Anton, and Bacon, L. R., Ind. Eng. Chem., *33*, 1011-19 (1941).
15. Wilson, J. L., and Mendenhall, E. E., Ind. Eng. Chem., Anal. Ed., *16*, 251-53 (1944).